The History and Progress of Metallurgical Science

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Birmingham University
October 30th, 1923

THE TEMPLE OF SCIENCE.

In this allegorical illustration, published in 1835, are shown the views prevailing early in the Nineteenth Century with regard to Science.

The History
and
Progress of Metallurgical Science
and its
Influence upon Modern Engineering

PART I: Relating chiefly to the City, Workers and University of Birmingham; with Notes on Education and Research.

PART II: Relating to Metallurgy and Metallurgical Chemistry, and their application to Modern Engineering.

Being an Address by

SIR ROBERT A. HADFIELD, Bt.

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Delivered before the

Birmingham University Metallurgical Society
in
The Metallurgical Department
of the University of Birmingham,
On Tuesday, October 30th, 1923.

Illustrated with

CINEMATOGRAPH, LANTERN SLIDES,
AND EXHIBITS.

ENGLAND

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"*I speak of that learning which makes us acquainted with the boundless extent of nature and the universe, and which even while we remain in this world, discovers to us both heaven, earth and sea.*"—CICERO (106-43 B.C.).

"*No pleasure is comparable to the standing upon the vantage ground of truth.*"—FRANCIS BACON (1561-1626).

"*I call a complete and generous education that which fits a man to perform justly, skilfully, and magnanimously all the offices, both private and public, of Peace and War. . . . I shall detain you no longer in the demonstration of what we should not do, but straight conduct you to a hillside, where I will point you out the right path of a virtuous and noble education; laborious indeed at the first ascent but else so smooth, so green, so full of goodly prospect and melodious sounds on every side that the harp of Orpheus was not more charming. . . . Be enflamed with the study of learning, the admiration of virtue, and stirred up with high hopes of living to be brave men and worthy patriots, dear to God, and famous to all ages.*"
JOHN MILTON in his "Tractate of Education" (1614).

"*Though all the winds of doctrine were let loose to play upon the earth, so Truth be in the field, we do ingloriously, by licensing and prohibiting, to misdoubt her strength. Let her and Falsehood grapple; who ever knew Truth put to the worse in a free and open encounter.*"
JOHN MILTON in his "Areopagitica" (1644).

Section I

Introduction

Opening Remarks.—The great pleasure I feel in addressing your Society this evening is increased by the fact that the invitation to do so came from my friend of long standing, Professor T. Turner, your much respected Professor of Metallurgy, who has been the President of your Society since its formation in 1905. A further reason for my gratification in being privileged to address you is that I have always admired greatly the Municipal activities of Birmingham, where John Bright and Joseph Chamberlain lived and worked. Your city has a proud position in our Empire, and in this Address it is my desire to pay a tribute of respect to its great work.

Since reading my first paper on Manganese Steel before the Institution of Civil Engineers, in 1888, I have presented 139 papers to Scientific and Technical Societies at home and abroad. That was, in some ways, an easier task than to face this evening a large audience of so many younger men, specially as I am bound to present much matter of a personal nature when endeavouring to describe some of my work in the field of Scientific Metallurgy.

I will however do my best, and beg you to pardon my shortcomings. At the conclusion of the Address, I shall be glad to try and answer any questions those in the audience may desire to put.

Each of those present to-night will receive a copy of this portion of the Address, Part I ; and of the Research Narrative No. 35, relating to Manganese Steel, published by the Engineering Foundation of New York. In addition, copies of Part II of the Address, in which reference is made more specifically to Ferrous Metallurgy, will be presented to those whose names will be selected by your President, Professor T. Turner.

As regards the exhibits, I trust that the varied collection shown this evening may be of interest ; they are described in the Table, a copy of which will also be handed to each of you. In one sense I regret that some of them bear the touch of war. The World now wants an era of peace ; but the memory of what our Empire went through and the gigantic task she took upon her shoulders must ever remain. The tale of what we did cannot be repeated too often, in order that we may be reminded of the deeds then accomplished on behalf of not only our own but the World's freedom.

War Work.—In my Lectures since the War I have always considered it desirable to make reference to the Great War from which we emerged victorious, thanks not only to the superhuman efforts of those in our Island Home, but also by reason of the magnificent service rendered by our Commonwealths, Dominions, India, and other outlying parts of the

Empire. Though in peace time we did not always appear to pull together, we spoke with one united voice when the Empire was attacked.

Sometimes it would seem as though the lessons of the War were already fading from our memories ; but surely the iron entered into our souls too deeply ever to be forgotten. We may generously want to forgive our enemies, who started the strife with all its attendant horrors, but we must never allow the memories of those terrible times to depart from us.

In the help that was rendered, the manufacturing and industrial centres of this country nobly did their utmost. In my own city, Sheffield, we did our best to help the nation in her hour of need, and we know that Birmingham did so too. A short time ago I asked Sir Graham Greene, who during the War was Secretary to the Admiralty, then Secretary to the Ministry of Munitions, and who now has charge of the War Records, what was Birmingham's share in the War. He replied that your city was one of the most important centres for the supply of war material and munitions, most of its work being carried out by private contractors and not directly through the Munitions Board or National Factories. He also stated that in addition to the large output of Projectiles, Small Arms, Ammunition, and other similar products, Birmingham was responsible for one National Shell Factory, one National Gauge Factory, and two National Rifle Factories. The total output from the National Shell Factory was many millions of shell, components including copper driving bands, gauges, trench mortar ammunition, brass and copper tubing, steel hammers, ammunition boxes, and hundreds of other products.

The Birmingham Board of Management rendered great help, for which the men at the front must indeed have been thankful. Your city, too, was largely responsible for those prehistoric looking productions known as "Tanks," which gave such magnificent service in the field.

Ancient and Modern Artillery.—Whilst for nearly three hundred years Birmingham has not directly felt the hand of war, in 1643 when besieged and taken by Prince Rupert, history tells us much destruction of life and property was then caused. I suppose the artillery of the attacking force at that time was scarcely up to the standard of that used by our Empire in the Great War. Had Prince Rupert been here this evening, I would have asked him to allow me to make a comparison for a few moments between his artillery, throwing cannon balls weighing a few pounds, and our modern guns, which throw monster projectiles weighing thousands of pounds each.

You will doubtless be interested in the following figures which give an idea of the high velocities and enormous energies developed in modern guns of small, medium, and large calibres. The energy developed by the small experimental gun of $10\frac{1}{2}$ cm. calibre with a muzzle velocity of 3,000 foot seconds, used at the proof butt of my firm, Messrs. Hadfields Ltd., Sheffield, can conveniently be compared with the energy of a Rolls-Royce car. This particular illustration has been chosen because I have used the car for more than ten years in sunshine and storm, in war time and peace. I can also truly state that I have never had even one involuntary stop with it in regard to the engineering side of its construction. This type of car has indeed proved a credit to British Engineering.

In December last I had a run in this car from my house just outside


Fig. 1 View of Butt.


Fig. 2. One Sixteenth Second Later. Impact on Plate.


Fig. 3. One Eighth Second Later than Fig. 2.

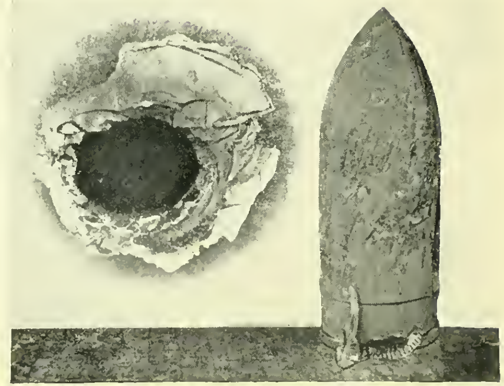


Fig. 4. The unbroken projectile, weighing nearly one ton, after perforating the thick armour plate.

This plate represents three remarkable photographs showing the impact effect of one of the Hadfield Armour Piercing Projectiles, weighing nearly one ton, fired at high velocity against thick hard-faced armour. Whilst the speed of the camera was too low to record the actual effect on the plate, it will be observed that the hole in the screen cardboard and the flash caused by the impact on the surface of the plate, all occurring in about one-seventieth part of a second, have been successfully obtained. It is probable that nothing of the same nature has ever before been shown, specially in view of the fact that the striking energy was very high, more than 60,000 foot tons. The fourth photograph shows the Hadfield large calibre projectile recovered unbroken and the hole which it has made in perforating successfully the thick hard-faced armour plate.

Sheffield to my residence in London, a distance of 172 miles. The car, loaded with five passengers and luggage, weighed $2\frac{3}{4}$ tons. We completed the distance mentioned, with 13 gallons of petrol, in 5 hours and 25 minutes, not counting the stop for lunch. I need hardly add that we interfered with no one's comfort on the road.

I should like to pay here a tribute to the high quality of our British roads, which reflect great credit upon the Civil and Road Engineers in our midst.

I am not showing the picture merely for personal reference, but to give you the following comparison, probably a curiosity of its kind, which I hope may be of general interest. On the left-hand side of the picture will be noticed an Armour Piercing Projectile of the calibre mentioned, $4\frac{1}{8}$ inches, which has passed through an armour plate 5 inches in thickness. This was fired from the gun which is used at the experimental butt of my firm for testing Armour Piercing Projectiles, and for testing ordinary and hard-faced armour to determine their respective qualities. The gun is of 50 calibres in length and the Projectile weighs $40\frac{3}{4}$ lbs.

At a speed of say 60 miles per hour, the Rolls-Royce car possesses an energy of 337 foot tons. The Armour Piercing projectile of the calibre mentioned, fired at 1,100 foot seconds velocity, leaves the gun in possession of the same energy, namely 337 foot tons. With this energy the Hadfield Projectile in question perforates unbroken a hard-faced armour plate 3 inches in thickness, placed 100 feet from the gun. The motor car has a bulk of about 450 cubic feet as compared with 0.082 cubic feet for the Projectile, yet this object of such small mass has stored in it as much energy as the large motor car travelling at 60 miles per hour.

For permission by the War Office and Admiralty to take the cinematograph pictures of loading and firing a 15″ gun which I am showing you this evening, I am indebted to Colonel B. R. Kirwan, C.B., C.M.G., Director of Artillery, and Captain J. O. W. Henley, R.N., Director of Naval Ordnance. I also have pleasure in acknowledging the help so freely rendered by Colonel D. Clapham, D.S.O., Superintendent of Experiments at Shoeburyness, assisted by Commander R. F. P. Maton, R.N., Experimental Officer. This 15″ gun weighs 97 tons, has a length of 45 calibres, that is 57 feet, and the projectile with its cap weighs 1,910 lbs. At its full elevation and with a muzzle velocity of 2,500 foot seconds, the range is 20 miles. Plate 1 represents photographs, probably the first ever obtained, from a camera placed within 50 feet, of the impact of a large calibre projectile striking with more than 60,000 foot-tons of energy against an armour plate.

I will now deal with the largest Naval gun yet constructed. Its calibre is 18″—a calibre, by the way, now prohibited as a result of the Washington Conference. The Armour Piercing projectiles for this gun weighing $1\frac{1}{2}$ tons each, were made by my firm during the Great War, and were capable of accomplishing the following feat. The gun weighs about 150 tons, and when elevated to 45° is able to carry its capped projectile weighing 3,320 lbs. loaded ready for firing, for a distance of something like 50,000 yards, or roughly 30 miles. I witnessed the first round fired from this gun at a hard-faced armour plate. The projectile, when capped and striking normally, is capable of perforating armour of the following thicknesses, the projectile itself remaining unbroken

and carrying its bursting charge through the plate. At point blank range a thickness of no less than 41 inches of hard-faced armour is perforated, which is equivalent to a wall of unhardened steel of about $4\frac{1}{2}$ feet. At 10 miles and 20 miles respectively, 22 inches and $12\frac{1}{2}$ inches of hard-faced armour of the latest and best type are perforated. Finally, at the extreme range of no less than 30 miles, the projectile passes intact through nearly one foot of ordinary steel armour.

In actual trials projectiles from this gun perforated hard-faced plates of a thickness nearly equal to the calibre of the gun, and this at an angle of 20°, at a velocity equivalent to a range of about 9 miles. Thus the heaviest armour afloat, when attacked by an 18″ gun, would not appear to be, metaphorically speaking, much better than cardboard.

The difficulty of hardening an Armour Piercing Projectile of these dimensions will be readily understood, for in the case of an 18″ projectile a volume of something like 10,000 cubic inches of steel, heated to a temperature of about 900° C. has to be quenched suddenly in a cold bath of oil or other medium. The effect of this treatment is to convert material which has originally when cold, a Brinell ball hardness of only about 200, to one of hardness between 600 and 700. To deal with the strains set up by the sudden change from material which is almost plastic to one of extreme rigidity is indeed a difficult problem, as can be well imagined when it is stated that steel of this rigidity readily scratches glass. In addition, it must be borne in mind that the rupture strains which are set up by the sudden cooling may continue, not for hours, but for days, weeks or even months afterwards. However, my firm was able to solve the problem satisfactorily, and supplied considerable numbers of these large Projectiles to our Navy. I do not remember a single one ever having been found cracked in store or on shipboard

Section II

The City of Birmingham and its History

Early History.—Whilst fully aware that my audience is well acquainted with the local history and work of Birmingham, as an outsider I should like to add my tribute of respect and admiration with regard to the important position this city has occupied in the history of our country. I have also gathered together some further facts now presented which I trust will be found of interest.

It appears that the first record of the city in the pages of history is that in Domesday Book, 1086 A.D. "Richard holds of William (Fitz Auscalf of Dudley) four hides in Bermingham." This designation was supposed to be derived from Bern or Beorn, the name of a tribal community.

The late Professor E. A. Freeman has also stated that the name of Birmingham pointed back to a family of "Berms"—"ing" being a family termination—who set up a homestead or "ham" here in the Midlands at some unknown date, when the Anglian tribes were settling in Mercia.

During the Middle Ages it appeared to be under the protection of the Berno de Berminghams. The de Bermingham family held the castle there, and some of the members of this family fought at Evesham. Their connection with the town appeared to continue for about five hundred years.

In Green's *History of the English People* it is stated that The Guild of the Holy Cross was founded in 1392 by the bailiffs and commonalty of Birmingham, its seal being shown in the accompanying illustration.

The members of the Guild were to be "as well the men and women of the said town of Birmingham, as men and women of other towns and of the neighbourhood who are well disposed towards them." The rulers were a master and wardens, and there was also a chantry with chaplains in which to celebrate divine service, that is, in St. Martin's Church. The Guild was to "do and find works of charity according as the ordering and will of the said bailiffs and commonalty shall appoint." Three wealthy citizens provided the endowment in lands and rents. One of the good works was the building of a "town-hall, otherwise called the gild-hall." King Edward VI's Commissioners in 1549 reported that "theare be relieved and mainteigned

uppon the possessions of the same guilde, and the good provision of the Mr and bretherne thereof, xii poore persones, who have their howses rent free, and alle other kinde of sustenance, as welle ffoode and apparelle as alle other necessaryes. Allso theare be mainteigned, with parte of the premisses, and kept in good Reparaciouns, two greate stone bridges, and divers ffoule and daungerous high wayes; the charge whereof the towne of hitsellfe ys not hable to mainteign; So that the Lacke thereof wilbe a great noysance to the kinges maties Subjectes passing to and ffrom the marches of wales, and an utter Ruyne to the same towne—being one of the fayrest and moste proffittuble townes to the Kinges highnesse in all the Shyre." The Guild was finally dissolved and its property confiscated. Out of the proceeds, the Free School was established. There then appears to have been nothing of special interest to narrate regarding the commonalty for more than a century later.

In 1643 Birmingham was taken and partly burnt by Prince Rupert. Under Charles II it advanced rapidly and its "manufacture of fire arms became considerable." In 1692, the town obtained its first Government contract, and "Steel Houses" (Steel House Lane) were started about 1700. St. Phillip's, now the Cathedral Church, was consecrated in 1715.

From the earliest times, iron was smelted in or near Birmingham—as was quite natural, seeing that all the necessary materials, iron ore, coal and limestone, were available practically on the spot. Hence, there grew up in the neighbourhood small works where the crude iron produced in the furnaces was converted into articles of general utility. These works were apparently no more than smiths' forges, and small crude foundries, their production including simple tools for the use of husbandmen and tradesmen, nails and chains, and later, as the craftsmen became more skilled, hardware and probably such implements of warfare as were then in use, also body armour.

This period may be assumed to represent the industrial activities of Birmingham down to the beginning of the sixteenth century, when Leland found in 1540: "Many smithes in the towne that use to make knives and all manner of cutting tooles, and many lorimers that make bittes and a great many naylors, so that a great part of the towne is maintayned by smithes." William Camden, who visited the town in 1586, noticed "a nest of smithes." In 1627, a book was published at Oxford which mentioned "Bremincham" as being inhabited by blacksmiths and forging sundry kinds of iron utensils.

In 1700, the first thread of cotton spun without the aid of human fingers was produced in a small building about six miles from Birmingham, whilst in 1741 the invention had made further progress, and yarn was spun by an engine turned by two asses walking round an axis in a large warehouse in the Upper Priory at Birmingham. This city therefore might have become a Cottonopolis.

Staffordshire without doubt has been one of the chief pioneers in the smelting of Iron Ore. In 1686 it practically supplied the whole country, and since 1740 the output of pig iron in the Midland area has been equal to about half the total output of Great Britain.

The work of Dud Dudley should not be forgotten, for he was the inventor and pioneer of that system of manufacturing cast iron which has helped to make the Midlands great. His life is referred to more fully later on.

In 1718 Darby revived Dudley's invention, which had remained in abeyance for over thirty years after his death.

Highly skilled moulder's work was carried out at Coalbrookdale about 1710 and onwards, showing that cast iron could be made, producing not only useful but artistic specimens of the decorative art, such as fire-backs and slabs which are prized all over the world.

Matthew Boulton, the son of a Birmingham manufacturer, established the Soho Works, and it was here that Watt worked. The necessity for the use of Watt's Engine was rendered still greater by the adoption in Staffordshire, in 1784, of Cort's puddling invention, which made it necessary to raise more fuel. James Watt made cast iron mixtures containing steely iron, thus producing in 1760 what is now called semi-steel. A fuller reference to the work of Watt and others is given later in this Address.

In 1750, so busy were the "smiths and founders" of Birmingham, that they petitioned Parliament to allow pig iron to be imported free from our American Colonies to keep them going. Between 1769 and 1804 there appears to have been a large number of patents taken out by Midland iron founders for making malleable cast iron, and it is curious to find that Matthew's patent of 1783 contains the germ of the Black Heart process now employed so successfully in America. In 1782 occurred the first use by foundrymen of the invention of Wedgwood, the Midland potter, for the more accurate measurement of high temperatures; this was used for over 100 years before the present pyrometer was brought out. The beginning of the nineteenth century saw a great impetus in the application of cast iron for constructional purposes, and we have the first cast iron bridge, of any size, erected in 1785 at Coalbrookdale on the Severn, where it is still in use. In 1794, Wilkinson of Sheffield took out a patent for a Cupola, the lines of which are practically the same as in use to-day, and 1800 saw Cupola melting taken up in the Midlands and the country generally. Metal patterns appear to have been adopted by local founders about 1810, although their use in other parts of the country was probably earlier.

In a paper on "The Iron Industry of South Staffordshire" read by Mr. Daniel Jones, F.G.S., at the Iron and Steel Institute Meeting in Birmingham, 1895, he describes a sight which will probably never be seen again. He mentions that when travelling from Birmingham to Liverpool on a dark night, about the year 1854, he was surrounded by a wild and brilliant scene. The country was apparently in uncontrolled flames; tongues of fire from 150 blast furnaces licked the sky, for the economist had not yet completed the utilisation of waste gases. Two thousand puddling furnaces sent forth their flames, whilst hundreds of mill furnaces, cupolas, air furnaces, and other flame generators, also thousands of pit fires dotted over the country, illuminated the scene.

PROMINENT FEATURES

Position and Population.—Birmingham stands from 290 to 650 feet above the sea level and is in a favourable and healthy position in this our country so fitly described by Shakespeare as "this little isle set in the silver sea." It is now the second city in England and the fourth city in the Empire in population. In 1700 it contained 15,000 inhabitants; in 1851, 400,000; in 1901, 522,000; in 1921 at the last Census 920,000;

and now approximately one million. In fact if the neighbouring towns in South Staffordshire and North Worcestershire are included, the total is well over two millions and growing all the time. The area of the city itself is 43,600 acres.

MUNICIPAL ACTIVITIES.—According to the City of Birmingham Financial Statement, 1922-23, the total Revenue or Turnover is practically 12 million pounds per annum, and the expenditure on Capital Account is 35 million pounds as against 28 millions five years ago.

In addition to the fact that building operations are now controlled according to a carefully prepared Town Planning Scheme, the roads are being considerably widened and improved, and provision is made for the construction of a ring road on the outer belt of the city. Canal development is also being considered on a large scale.

Your city has in modern times been distinguished for its liberality and freedom of thought, whether in politics or religious views. Nowhere has the system of Municipal Government been more admirably and fully developed, nor is there a Municipality more distinguished for enlightened promotion of popular culture. The city played a large part in the educational movements which led to the first Education Act in 1870.

Birmingham is to be congratulated too on the recent statement by Mr. Justice McCardie, who pointed out that in three successive Summer Assizes the number of cases of serious kind was extremely small. Birmingham is therefore in this, as in other respects, conspicuous amongst the great cities of the world, and has every reason to be proud of its citizens.

The present Lord Mayor of Birmingham is Sir David Davis, Kt., who was born in Birmingham in 1859. He was educated at the King Edward School, to which I have already referred, and University College, London. Sir David has been a member of the City Council for twenty-two years, and is a Life Governor of the Birmingham University. During last winter he raised the large sum of £45,000 for the relief of the unemployed of the city, and in the last Birthday Honours received a knighthood in recognition of his services as Lord Mayor.

PLACES OF INTEREST.—No district is more interesting on its historical side. You have within easy range of the city such places of historic interest as Coventry, Warwick with its famous Castle, Kenilworth, and Stratford-on-Avon. Meriden, about twelve miles from Birmingham, is reputed to be the centre of England.

OTHER SPECIAL POINTS.—Birmingham has been described as the "Workshop of the World," and it is without doubt one of the most important parts of the British Empire with regard to its manufacturing facilities, its output comprising a particularly large variety of products. It was made a Borough by the Reform Act in 1832, at the same time as the City of Sheffield. Its first Railway was opened in July, 1837, between Birmingham and Liverpool, and was known as the Grand Junction.

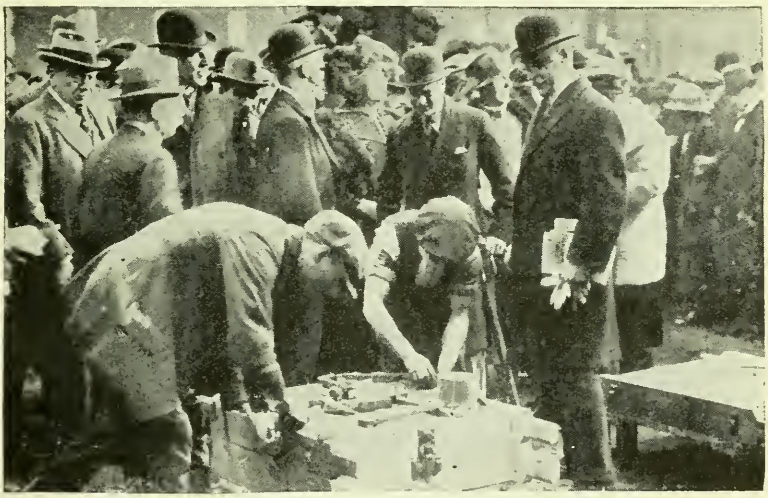
ROYAL VISITORS.—Like Sheffield, you have had both the Prince of Wales and the Duke of York to see you recently. From what I saw in Sheffield, and heard as regards Birmingham, the Civic welcomes of both cities were quite unequalled in the annals of the Empire! Whether one was better than the other, wild horses would not drag me to decide.

MEDALLION OF H.R.H. THE PRINCE OF WALES,
duly impressed and signed by him in the sand mould, and afterwards cast of Manganese Steel in his presence, on May 29th, 1923.

With regard to the visit of the Prince of Wales to the East Hecla Works of my firm, Messrs. Hadfields Ltd., Sheffield, on May 29th, 1923, it may be of interest to show, Plate 2, the Medallion in Manganese Steel cast by H.R.H. which was signed by him in the sand mould. The illustration given below represents the mould about to be closed. When I handed H.R.H. the facsimile stamp to impress the mould, he jokingly accused me of being a party to forging his signature, and only let me off serious pains and penalties upon my undertaking that he should be presented with the Medallion carrying his signature. This Medallion he has been kind enough to re-present to the Weston Park Museum, Sheffield, where it now rests as a memento of his visit to our city and as a specimen of the steel founder's art.

PAST GREAT MEN IN BIRMINGHAM AND DISTRICT

Prominent Men of the Past.—In describing briefly some of the great men of the past who have helped to make the City of Birmingham what she is to-day, and to render her famous in the annals of our Empire,



Closing of the Mould after the Prince of Wales had impressed his signature.

I need offer no excuse for this retrospect, for is not a correct conception of the living past a guide and help to us of to-day? It is the past which has helped to make the present what it is. Even so far back as B.C. 300 the Philosopher Publius Syrus said: "Each present day is the scholar of yesterday."

It is useful therefore for the younger men growing up amongst us, to study the history and character of those men of the past to whom we are so greatly indebted. They represent men of thought and action who struggled long and strenuously in their day and generation to advance knowledge.

Feeble as may seem the knowledge existing in those earlier times compared with ours of to-day, do not let us forget that it was these

earlier workers who fanned the flame of inquiring minds. Let us remember, too, that "from small beginnings great things spring."

It is hoped that the portraits, which in certain cases accompany the descriptive matter, may lend an added interest to those reading this Address.

The names selected from those workers of the past associated with Birmingham are mainly connected with the development of the following branches of science: *Engineering*—Savery, Boulton, Watt, Murdoch, Siemens; *Metallurgy*—Dud Dudley, Gore, Percy, Greenwood; *Chemistry*—Priestley; *Electricity*—Kapp. There are others, too, who might have been mentioned, but want of space forbids.

Sir Oliver Lodge, although no longer in Birmingham, is happily still with us: I do not therefore refer to his great work here, as this is dealt with later, when describing the prominent men of the present day.

No mention of the past worthies of Birmingham and district, in whatever connection, is complete without a reference to the immortal Shakespeare. Wide as were his understanding and acquaintance with the world, there is good reason, as I hope to show, for giving him a special place even in connection with so specific and technical a subject as Metallurgy. Although he may not have been a worker in this branch of science, it is evident from the information I have been able to get together and quote, also from his own repeated references, that he had more than a passing knowledge of and interest in the metal iron and its applications.

This, combined with Shakespeare's name and fame, makes me feel that there is every justification for commencing this portion of my Address by referring to him, and to what he has said regarding the metal iron.

SHAKESPEARE (1564-1616).—Birmingham has in the first place the proud privilege of being very near the Anglo-Saxon shrine, Stratford-on-Avon, where lived William Shakespeare, whose portrait is shown in Plate 3, the greatest English poet, dramatist, and human philosopher, not only of England but probably of any country. His comedies, histories, and tragedies are unique, and many of his utterances are firmly ingrained in the language of our daily lives. In these references to famous men of the district I will therefore first speak of him, that is as I regard his connection with the branch of science in which we to-night are most interested. Some may say, What had Shakespeare to do with Metallurgy? Perhaps more than has been commonly thought, and amongst others for the following reasons.

Not long ago, when staying at Stratford, I visited the Shakespeare Memorial Library, then in charge of Sir Oliver Lodge's brother, Mr. Ernest Lodge, who enabled me to make investigations as to whether Shakespeare with propriety might be said to have been interested in Metallurgy. The result was that many references were found, some of which will now be mentioned.

I also corresponded and have had conversation with the well-known Shakespearean scholar, Sir Sidney Lee, who was kind enough to look into the subject, and found an interesting reference to a mysterious Overseer and Legatee under Shakespeare's will—by name Thomas Russell, who was interested in Metallurgy.

This Legatee and friend, Thomas Russell, alone of all the persons

SHAKESPEARE
(1564-1616)

mentioned in the Will of Shakespeare, bore the dignified designation of "Esquire." He received £5, and was also nominated one of the two Overseers, Francis Collins being the other. There is no proof in the local records that Russell was a resident in Stratford, and he was in all probability a London friend. It was known that Shakespeare had opportunities of meeting him in London, and, in the dramatist's later life, Russell enjoyed a high reputation there as a Metallurgist, obtaining patents for new methods of extracting metals from the ore, including making and extracting of copper out of copper ores and other mineral substances; making of brimstone and Danske copperons; making copper out of any copper mines within England and Ireland; working and making of copper by a new way of dissolving the ores in water or liquor. Full particulars of these patents granted in the years 1609, 1610 and 1614, can be seen at the Public Record Office, Chancery Lane.

As early as 1608 Sir Francis Bacon was seeking this same Thomas Russell's acquaintance on the double ground of his scientific ingenuity and his useful influence. It is stated that Shakespeare owed to Drayton the acquaintanceship with Russell, which Bacon also aspired to share. Shakespeare was probably, therefore, interested in the affairs of his friend Russell and no doubt discussed with him Metallurgical subjects of the times. He seems often to have visited Birmingham, and seen its Metallurgical activities previously mentioned.

Another and particularly curious instance as to the Poet's interest in iron is that mentioned to me by Mr. F. C. Wellstood, M.A., Secretary and Librarian to the Trustees and Guardians of Shakespeare's Birthplace and Deputy Keeper of the Records of Stratford-on-Avon. He has informed me that among the exhibits in the Birthplace Museum is a document witnessed by the dramatist's father, concerning his neighbours in Henley Street in 1575. It is a deed of sale by William Wedgewood, of Stratford, *tailor*, to Edward Willes, of Kyngsnorton, yeoman, for £44, of two tenements in Henley Street occupied by Wedgewood, "betwyne the tenement of Richard Horneby, *blacksmith*, of the east part, and the tenement of John Shakesper, yeoman, of the west part," 20 Sept., 1575. Among the witnesses are John Shakesper and Richard Horneby.

Shakespeare was eleven years old at the date of this deed, and his father's house where he resided was next door to that of William Wedgewood the *tailor*. The forge and smithy of Richard Horneby adjoined Wedgewood's shop. Horneby's premises now form the Birthplace Ticket Office.

Horneby's forge and smithy must have been frequently visited by the poet in his boyhood days, and no doubt suggested to him later on in life the vivid picture which he gives in *King John*, *iv*, 2, 193:—

I saw a *smith* stand with his hammer, thus,
The whilst his iron did on the anvil cool,
With open mouth swallowing a *tailor's* news;
Who with his shears and measure in his hand,
Standing on slippers,—which his nimble haste,
Had falsely thrust upon contrary feet.

In view of the statement made by Mr. Wellstood, as to the Horneby Forge and Smithy being next door to the house where Shakespeare lived

in his boyhood days, the references in these lines to the "smith" and the "tailor" are of peculiar and apposite interest. How vividly are brought before us the brawny smith acquiring news from the gossiping tailor! Moreover, as a friend of mine says, this little instance proves in a striking manner that the man who uttered these words was certainly not Bacon or some other individual, but William Shakespeare himself, who had seen and known the smith and tailor so graphically described.

In his various plays, Shakespeare makes reference to iron about forty-eight times; to steel, sixty-four times; gold, one hundred and twenty-one times; silver, fifty-four times; also to fire and fuel, a considerable number of times. There are also many indirect references of Metallurgical nature, the following being probably some of the most interesting ones.

In *King John, iv*, 1, he said: "Are you more stubborn-hard than hammer'd iron"; 2 *Henry IV, ii*, 3, "Then join you with them, like a rib of steel to make strength stronger"; *Coriolanus, i*, 9, "When steel grows soft as the parasite's silk"; 2 *Henry VI, v*, 1, "Here is now the smith's note for shoeing and ploughing iron"; *Antony and Cleopatra, iv*, 4, "I'll leave thee now like a man of steel"; *Twelfth Night, iii*, 3, "My desire more sharp than filed steel, did spur me forth"; *Troilus and Cressida, i*, 3, "As true as steel"; *Two Gentlemen of Verona, iii*, 2, 79, "Whose golden touch could soften steel and stones. Make tigers tame"; *Richard II, iii*, 2, "With hard bright steel and hearts harder than steel"; *Venus and Adonis*, "Strong-temper'd steel his stronger strength obey'd." Then in *Hamlet, iii*, 2, "Here's metal more attractive," could surely have had no other reference than to iron, easily the King of Metals. Again in *Henry VIII, iii*, 2, "Now I feel of what coarse metal ye are moulded," which could hardly have had reference to iron!

Indirectly it appears that amongst metals the one known as "Ferrum," to which we Ferrous Metallurgists pay homage, seems to have had special preference in Shakespeare's mind, for in *Love's Labour Lost* has he not said of at least one non-ferrous metal, lead, "Is not lead a metal heavy, dull, and slow"; and in a vein of sarcasm, "As swift as lead"; of gold, "The ill qualities of gold characterised" (*Timon of Athens, ii*, 1); "You are an Alchemist, make gold of them" (*Timon of Athens, v, i*, 117). Shakespeare did not refer to iron in such terms, and his mention of copper is only four, and of brass, fourteen times. As regards other metals their separation had not been effected and they were therefore unknown to him. As some comfort to the non-ferrous friends amongst us this evening, it may be of interest for them to know that Chantrey, the great Sculptor, who lived in Sheffield, in his reverence for classic Metallurgy had a bronze razor made with which it is believed he martyred himself whilst shaving. Since then however none has been found so hardy and devoted as to follow his example.

In view, therefore, of the foregoing references regarding iron, and with all due respect to my non-ferrous friends—as on no account would I wish to hurt their feelings—it would appear that Shakespeare leaned more towards ferrous than non-ferrous Metallurgy. What would he have thought had he known that in about 300 years the world's annual output of iron, the giant metal of our times, would reach some seventy

MONUMENT TO DUD DUDLEY IN ST. HELEN'S CHURCH, WORCESTER.

million tons—a total which will undoubtedly soon pass the one hundred million tons mark.

How strikingly, too, does Shakespeare appeal to the Metallurgist, whether ferrous or non-ferrous, when he says, in *Othello*, *v*, 2, " Roast me in Sulphur ; wash me in sleep down gulfs of liquid fire." To those who have handled " gulfs of liquid fire," whether from the blast furnace, the Bessemer and Open Hearth Steel melting shops, or the electric furnace of still later origin, this is a striking allusion to certain well-known characteristics of the calorific side of our science, in which both ferrous and non-ferrous investigators can heartily agree.

From all this evidence, internal and external, it will be seen that Shakespeare was undoubtedly interested in Metallurgy, and he might fairly have been elected Honorary Member of the Iron and Steel Institute and the Institute of Metals had these Bodies then existed !

Dud Dudley (1599-1684).—Let us now turn to the work of one who was closely connected with practical metallurgy, namely, Dud Dudley, who was born in 1599 about eight miles outside Birmingham. In 1620 he erected his furnaces at Bradley, nine miles away from the city. The world owes to him the method of smelting iron by means of coke converted from " pit-coale," instead of by charcoal as formerly used. But for his invention the manufacture of cast iron on its present immense scale would have been impossible. He took a prominent part in the Civil War as a Royalist, and was a Colonel in the Army of Charles I, and General of Ordnance to Prince Maurice. In 1642 he was engaged in making cast iron cannon at his foundries for the Royalist troops.

Dudley, in collaboration with Simon Sturtevant and John Rovenzon, wrote in 1665 his book on the manufacture of iron, *Metallum Martis*, or " Iron made with Pit-Coale and Sea-Coale." He spoke of this country being able to supply " His Sacred Majestie's other Territories with Iron and Iron Wares and Steel also, by Iron and Steel made with Pit-coale, Sea-coale, and Peat ; and thereby be helpful unto themselves and England and all Plantations of His Majestie's, on this side and beyond the line." As showing the ignorance and mystery prevailing at the time regarding Metallurgy even such a pioneer as Dudley says, with reference to iron manufacture, " I might here speak somewhat of Superior Planets producing Metal ; Saturn, Lead ; Jupiter, Tin ; and Mars, Iron." This was evidently before the days of spectrum analysis ! It was also Dud Dudley who obtained a quaint acknowledgment of his service to Captain John Copley regarding the manufacture of iron. It runs as follows under date December 30th, 1656 : " Memorandum—The day and year above written, I, John Copley, of London, Gentleman, Do acknowledge that after the Expense of diverse Hundred Pounds to Engineers, for the making of my Bellows to blow, for the making of Iron with Pit-coale or Sea-coale near Bristow, and near the Forrest of Kings-wood ; that Dud Dudley, Esq. did perform the blowing of the said Bellows at the Works or Pit above said ; a very feisible and plausible way, that one man may blow them with pleasure the space of an hour or two ; and this I do acknowledge to be performed with a very small charge, and without any money paid to him for the same invention."

In the church of St. Helen's, Worcester, there is a large monument to Dud Dudley fixed on the south wall in two columns ; this is shown in the accompanying Plate 4. I am indebted to Colonel E. H.

Nicholson, of Newark, for the following translation of the inscription on the monument :—

Dust and Shadow—Smoke.

Dust thou are and unto dust shalt thou return. Gen. iii, 19.

For we are but of yesterday and know nothing ; because our days on earth are a shadow. Job viii, 9.

Dodo.

Dodo Dudley, Commander of 1,000 men. Son of Edward, late Lord Dudley, dear to his Father, a most loyal subject and servant of the Royal House, a useful vassal of the Court, a champion of the Church, and a stanch upholder of English Liberty and Law. Often captured in the year 1648, once sentenced to death and yet not beheaded. He lived as an old man, ever of unshaken virtue, to see the crown reborn again (i.e. the Restoration).

The longest life but puts off death and does not banish it.

But it is a matter of much concern whether one dies to-day or to-morrow.

It is inevitable, therefore one shuns it, yet it is not to be dreaded.

Mai 1630
F.H. A.F. D.D.
F.A. I.E. I.V.
E.S.

Here lies

Elianore, wife of the aforesaid Dud Dudley. Daughter of Francis Heaton (by Mary his wife, daughter of Francis Dingley of Charlton) son of Francis Heaton and grandson of George Heaton, lord of the manor of Winkell in Lincolnshire, who married Joan, one ot the coheirs of Sir Robert Byfield (the rest married to Byron Molyneaux and Sir Miles Bushley). William Heaton his grandfather married Sir George Merry's daughter, of An Bright in Lincolnshire. She was born 1601, the 25th of December, at 6 of the clock, 4 Ser. P.M. pol. 52.24. died 1675, Decemb. 3, at 3 of the clock.

O my beloved pilgrim this is the lot of me, thy wife to-day,

To-morrow my husband, it will be thine.

Death treads on all our heels,
Thou canst not escape it.

Though spent my breath, I still will hope.

Let us now survey the work of six of the early investigators in the district who helped to develop Steam Engineering.

Papin (1647-1714).—So far back as about A.D. 50, Hero of Alexandria is credited with the earliest known employment of steam as a motive agent, but the next step of any importance does not appear to have been taken until 1700 years later when Papin, of French origin, studied the subject of steam power. It is in no spirit of depreciation of Watt's great discovery and invention, which are referred to later, that attention is called to the work of Professor Dionysius Papin, M.D. (1647-1714), Fellow, and at one time Secretary of the Royal Society, whose portrait is shown in Plate 5. Whilst he was not connected with Birmingham a reference to the development of the use of steam as a motive power would certainly be incomplete without his investigations being mentioned.

In 1681 he published a paper on "A New Digester for Engines," and later, in 1690, a paper in the *Acta Eruditorum Lipsiæ* entitled "A New Method of obtaining very great Moving Powers at Small Cost." On these papers are based Papin's claims to be considered one of the early originators of the steam engine. Papin availed himself of the apparatus of Otto Gueriche and worked out the important fact that if a closed cylinder were filled with steam and the steam then allowed to condense, a vacuum would be formed within the cylinder, and that consequently a movable piston fitted to the interior of the cylinder would then fall under the pressure of the atmosphere.

About the middle of the 17th century the important discovery had

DIONYSIUS PAPIN, F.R.S.
(1647-1714)

been made that the atmosphere was a fluid possessed of weight, the pressure due to which could be excluded at will from the interior of a closed vessel so as to obtain a vacuum ; this was the foundation of the development of the steam engine.

In Papin's experiment there was some suggestion of the principle of Newcomen's engine, but the proposal was abandoned by him.

Previous to this, he had made an unsuccessful attempt to obtain a vacuum by the explosion of gun-powder in the small cylinder beneath the piston, a description being published in September, 1688, in the *Acta Eruditorum Lipsiæ.*

It is possible that Papin may have had his attention drawn to the subject by reading a book published in London in 1651 by an unknown Author, entitled *Invention of Engines of Motion lately brought to perfection whereby may be despatched any work now done in England or elsewhere (specially works that require strength and swiftness), either by wind, water, cattel, or men, and that with better accommodation and more profit than by anything hitherto known or used.*

Although Papin overlooked the difficulties of applying power to various mechanical processes, he was best known in England on account of his Digester, described by him in the paper previously mentioned. His works are rare and it is doubtful whether more than a single copy of the Memoir of 1690 is in existence. The fact that Papin was at one time Secretary of the Royal Society shows that he must have been a man of considerable knowledge.

Papin described in 1707 an inferior sort of steam engine, in the preface to a little work entitled *Nouvelle manière d'élever l'eau par la force du feu*, printed at Cassel.

Besides showing the power of steam by the famous experiment of his Digester, he proposed in a pamphlet printed in 1695, the construction of a new pump, the pistons of which were to be moved by the steam of boiling water.

Whilst Papin's early work is fully admitted, as a well-known French writer at the time said : " It is a great thing even to suggest this idea, but it remained to realise and execute it in a simple and convenient manner. The English, referring chiefly to Watt, are the first who have succeeded in that."

Savery and Newcomen (1608-1729).—In 1698 Thomas Savery patented and constructed what was known as the " fire engine." It is possible that he was indebted to the Marquis of Worcester. In any case, however, it may be safely said that he was the first to utilise fuel as a practical means of performing mechanical work.

Then came Newcomen (1663-1729) assisted by John Cawley, both of Dartmouth, who following in Papin's steps, succeeded prior to 1712 in perfecting the atmospheric engine, from which the growth of the modern steam engine can be clearly traced.

Later on Newcomen and Savery seem to have come to an understanding with each other regarding their patents. Their type of engine remained for upwards of sixty years for draining mines, in fact, down to 1789 nearly 100 engines had been built for the northern districts, and about half that number for Cornwall.

Watt (1736-1819).—When thinking of the great Engineers of the past in Birmingham, the name that rises first and most prominently before us is that of James Watt, whose portrait is shown in Plate 6.

The fame of Watt's great work in the development of the steam engine is world-wide. His discovery of the method of condensing steam in a vessel entirely separated from the cylinder occurred in 1765. He took out his first patent in January, 1769, and this was renewed by Act of Parliament in 1775. Later, in 1778, came his engine on the expansion principle, and his double acting engine in 1781. In these days of rapid progress it may be interesting to state that James Watt once called Richard Trevithick a murderer, for proposing to operate boilers at the "dangerous" pressure of 60 lbs. per square inch. To-day at Rugby a plant is I believe being designed under the Benson system for a minimum boiler pressure of 3,200 lbs. In view of your recent Centenary celebrations of Watt and his work it is not necessary for me to add anything further here. The Institution of Civil Engineers have honoured his memory by founding the Prize of the Watt Gold Medal, which is awarded annually. The large statue in Westminster Abbey "James Watt, the Improver of the Steam Engine," was by Chantry, the Sheffield sculptor, whose body was buried at Handsworth.

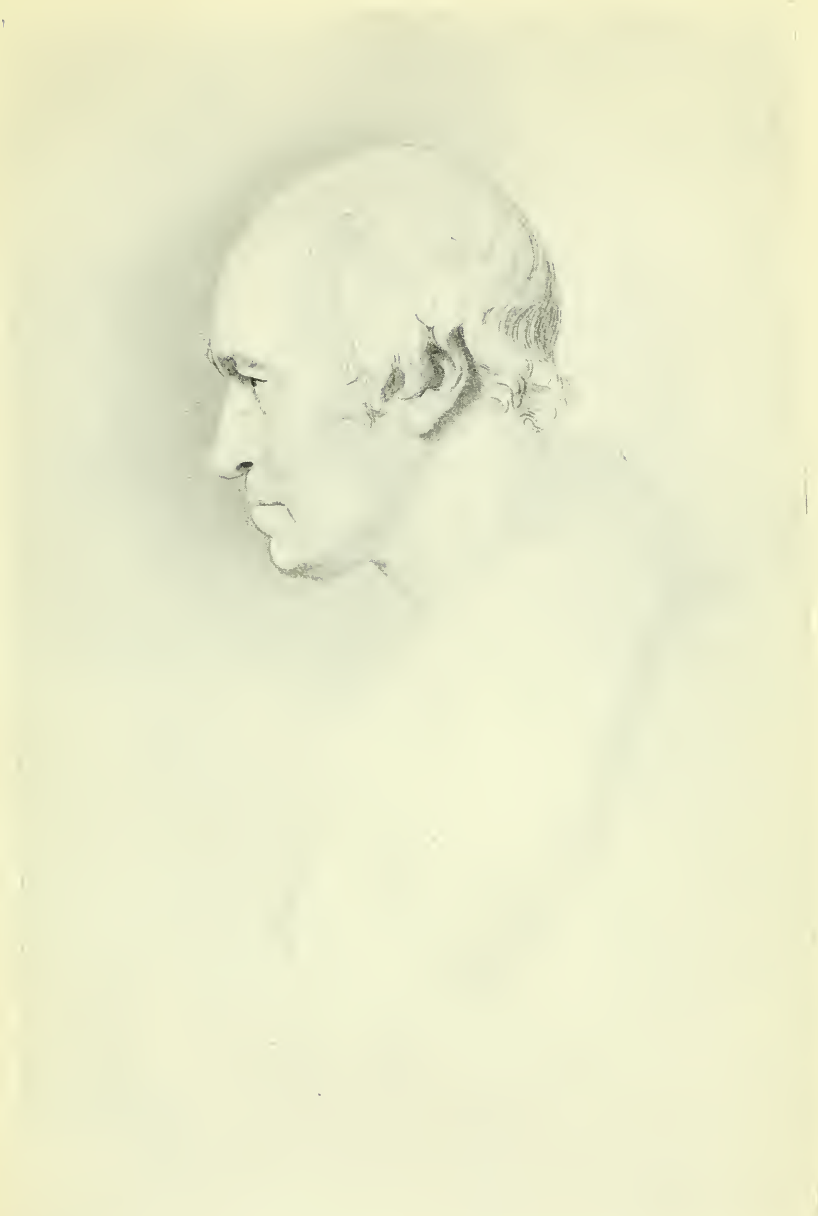
BOULTON (1728-1809).—Watt was ably assisted by Matthew Boulton, and later by William Murdoch. Boulton, whose portrait is shown in Plate 9, was born in 1728, and started the famous Soho Works in 1762. James Watt joined him in partnership in 1769, and Murdoch came into the firm about 1777. This wonderful triple combination gave us the steam engine, gas lighting, and other industrial developments. William Brunton, the inventor of the first mechanical stoker, was also one of the Soho group of Engineers. His work in this field and, indeed, the whole early history of mechanical stokers, is discussed in "Mechanical Stoking" (Pitman's) by Mr. David Brownlie, who has devoted much time to the study of the subject.

MURDOCH (1754-1839).—William Murdoch, whose portrait is shown in Plate 7, was born in 1754 at Lugar, Ayrshire. He was the son of a small farmer, and as rumour insists, supposed to be of Flemish extraction. After leaving his native village in 1777, he obtained a situation as mechanic with Boulton and Watt. In 1792 he lighted his house and office at Redruth, Cornwall, with gas and in the same year erected his first Gasometer at Birmingham, which gave continuous service from this time until 1911, that is for nearly 120 years. This still stands, though in partial ruin, at the works of Messrs. Avery, Soho Foundry, near Birmingham. Until comparatively recently the gas holder was intact and was used for the storage of Dowson gas.

In 1798 Murdoch left Cornwall to take up a prominent position at the Soho Works, where he constructed gas-making apparatus on a larger scale: this included lighting their principal building, and various new methods were practised for washing and purifying gas.

Murdoch designed the Gasometer whilst some of the Gas Companies in London were struggling with the use of gas balloons to store the gas. This was the forerunner of the modern gas holders, some of which have reached huge proportions as in the case of that of the Gas Light and Coke Co. in London, which has a diameter of 300 feet and a capacity of 12,000,000 cubic feet.

In 1808 he read a Paper before the Royal Society of Arts with regard to his installation of gas lighting at the Phillips and Lees Cotton Mill in Manchester, containing some 900 gas burners. For this he was awarded by the Society the Rumford Gold Medal.



James Watt

(1736-1819)

In a paper on "Corrosion of Ferrous Metals," read before the Institution of Civil Engineers in 1922, I referred to the work of Murdoch and the original Gasometer erected by him in Birmingham in 1792. An analysis of the iron used in its construction, taken from a specimen furnished to me by the courtesy of Messrs. W. & T. Avery, was made at the Laboratory of my firm and showed the following composition :—

C	Si	S	P	Mn	Cu	Fe
.04	.28	.045	.550	.07	.02	98.9 per cent.

The total impurities in the iron, that is C, Si, S, P, Mn, and Cu, amounted to .99 per cent. which hardly brings it under the category "Pure Iron." Yet, as already mentioned, the Gasometer in question was at work until quite recently, satisfactorily resisting the corrosive effect of wind and weather.

PRIESTLEY (1733-1804).—Turning now to the study of Chemistry, Dr. Priestley's name must be remembered. He was born in 1733 at Fieldhead, Birstal, near Leeds, which had been occupied by his father and grandfather, and afterwards by his sister, Mrs. Crouch. He lived at Warrington from 1761 to 1768, in Leeds from 1769 to 1773, in Birmingham from 1780 to 1791, and then went over to the United States in 1794. His last letter written in England was dated February 7th, 1794. He arrived in New York on June 4th of the same year and died in that country in February, 1804. A statue to his memory was unveiled by Professor Huxley at Birmingham in August, 1874.

Priestley had a meeting with Dr. Benjamin Franklin, during one of his visits to London, which caused him to take up the study of Electricity, and eventually to write a history of the knowledge then existing on that subject. This, together with several new experiments on Electricity won him not only outside reputation but resulted in his election as Fellow of the Royal Society in 1766. It is interesting to note that Benjamin Franklin was one of Priestley's proposers when his name was submitted to the Royal Society for election.

Priestley, whose portrait is shown in Plate 9 was an extraordinary combination of Theologian, Philosopher, and Chemist. Somewhat singular to say, it was not until 1780 that he abandoned the subject of Electricity for Chemistry.

By his great discovery of Oxygen, Priestley made for himself an undying name. Whilst this contained the germ of the modern Science of Chemistry, yet, owing to his blind faith in the phlogistonic theory, the significance of his work was to some extent lost upon him. The first announcement was made by him in a letter dated March 15th, 1775, which was read at the Royal Society on May 25th of that year.

Priestley's account of the discovery of Oxygen is given in his own words as follows : "Having procured a burning lens, I proceeded with great alacrity to examine by the help of it, what kind of air a great variety of substances would yield, putting them into vessels filled with quicksilver, and kept inverted in a basin of the same. After a variety of other experiments, I endeavoured to extract air from mercurius calcinatus *per se* ; and I presently found that, by means of this lens, air was expelled from it very readily. Having got about three or four times as much as the bulk of my materials, I admitted water to it, and found that it was not imbibed by it. But what surprised me more than I

can well express, was that a candle burned in this air with a remarkably vigorous flame. I was utterly at a loss how to account for it." His experiments showed him that this air "had all the properties of common air, only in much greater perfection," and he called it "Dephlogisticated air," regarding it simply as very pure ordinary air.

It was in Paris, however, in October, 1774, where Priestley, according to his account, spoke with the great French Chemist, Lavoisier, of the experiments he had already performed, and those he meant to perform, in relation to the new Gas. Fifteen years later Priestley declared specifically that he had told Lavoisier of his experiments during this visit to Paris. This fact is mentioned because at one time it was thought that Lavoisier might have been the first to make the great discovery, but this was not so.

Apart from his work in connection with the discovery of Oxygen, Priestley also discovered Carbon Monoxide. His invention of the Pneumatic Trough was of much service, enabling him not only to discover new gases, but to investigate more fully the properties of many already partially known.

There were serious riots in Birmingham in 1791, probably meant to commemorate the French Revolution in 1789. These partly took the form of an attack, amongst many others, upon Priestley's house at Fair Hill. Fortunately the Doctor was able to get away in safety, but his house was completely gutted. In this connection I present an interesting picture in this Address (Plate 8) showing the mob at work. This has been obtained from a valuable set of memoirs referring to Dr. Priestley's life and work got together by Dr. James Yates, F.R.S., and now in the Royal Society Library. It may be mentioned that Mr. Samuel Tertius Gallon afterwards purchased the site, and rebuilt the house, naming it "The Larches."

A local account of the destruction is set forth in the following words: "They destroyed an apparatus of philosophical instruments, and a collection of scientific preparations for ascertaining the powers and extending the knowledge of Nature, of such number and value as perhaps no individual except Dr. Priestley could have been deprived in any day or country."

An interesting letter addressed to the Town of Birmingham was written by Dr. Priestley regarding this mob attack on July 19th, 1791, in the following terms:—

July 19, 1791.

To the Inhabitants of the town of Birmingham.

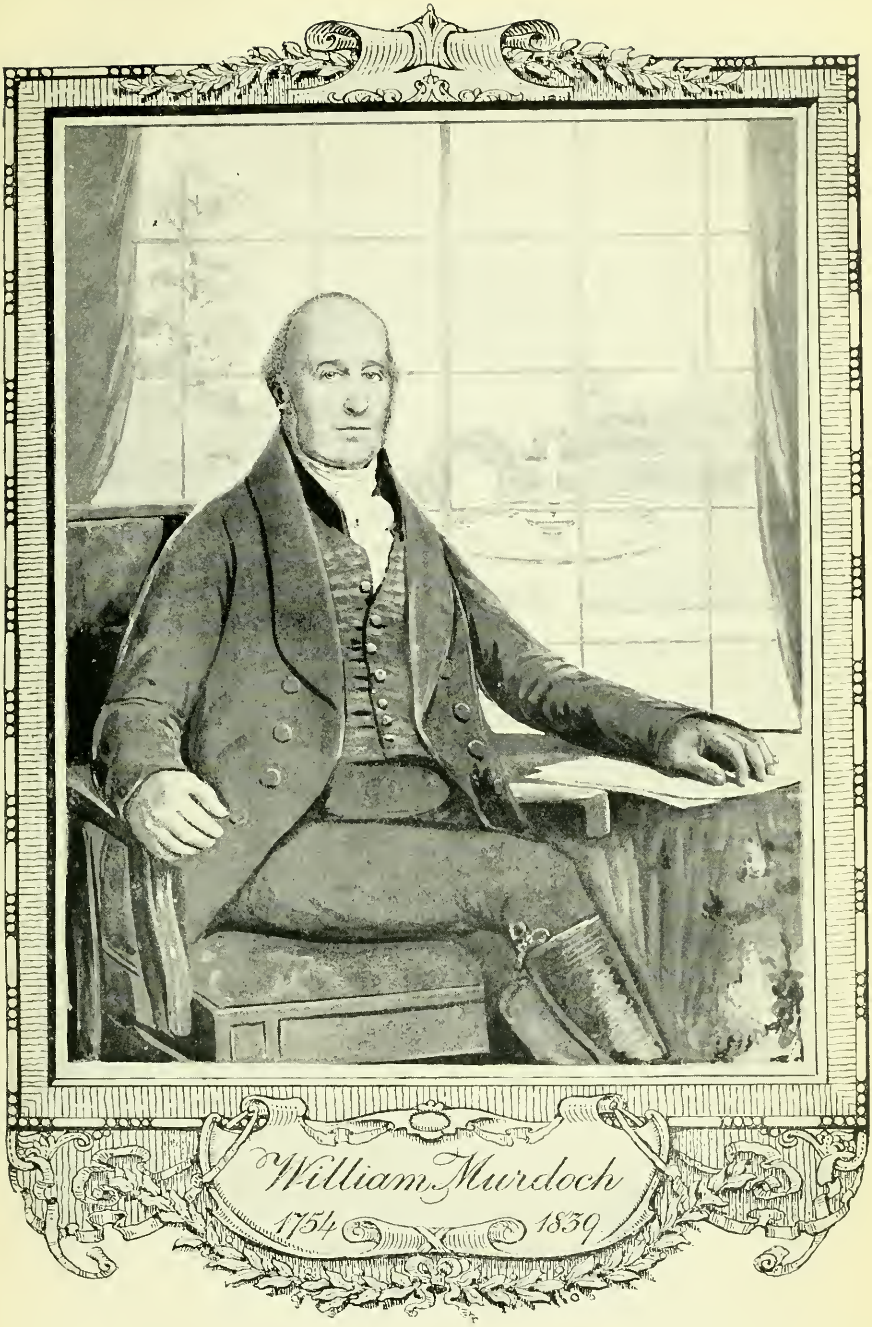
My late Townsmen and Neighbours,

You have destroyed the most truly valuable and useful apparatus of philosophical instruments that perhaps any individual, in this or any other country, was ever possessed of, in my use of which I annually spent large sums with no pecuniary view whatever, but only in the advancement of Science, for the benefit of my country and mankind. You have destroyed the Library corresponding to that apparatus, which no money can re-purchase, except in course of time. But what I feel far more, you have destroyed manuscripts, which have been the result of the laborious study of many years, and which I shall never be able to recompose; and this has been done to one who never did, or imagined, you any harm.

In this business we are the sheep and you the wolves. We will preserve our character and hope you will change yours. At all events we return you blessings for curses, and hope that you shall soon return to that industry and those sober manners for which the inhabitants of Birmingham were formerly distinguished.

Yours faithfully,

J. Priestley.


William Murdoch
1754 1839

An old proverb says: "The ship that carries most sail is most buffeted by the winds and storms." It was so with Priestley; his mental capacity was great, but most severely was he buffeted specially in the later portion of his career. Nevertheless, he manfully overcame all obstacles and the World is greatly indebted to him for the most valuable developments he helped to bring about, including his important discovery of Oxygen, an Element now being used on a large scale for many purposes.

PERCY (1817-1889).—Through the kindness of Professor Turner, I have been able to obtain some interesting information with regard to one of the noted Metallurgists of our time—Dr. John Percy, M.D., F.R.S., who was for so many years connected with Birmingham. His portrait is shown in Plate 10.

Some of my earliest studies of Metallurgy were made from Percy's excellent works including those relating to both Ferrous and Non-Ferrous Metallurgy, Fuel, and other kindred subjects. His well-known and classic books were of the greatest service to many of us studying this subject some thirty or forty years ago.

Percy went through a course of training at the University of Edinburgh, which he left in 1838, having gained many prizes. He then proceeded to Paris, where he took up further studies, which brought him in contact with some of the leading Chemists of his day. This developed a taste for Chemical Research, in which he was afterwards destined to acquire so high a reputation. Having completed his academical career in Paris, he travelled for a time, and on returning to England began to practise as a medical man at Birmingham.

In 1839 he married his cousin Grace, the only child and heiress of John E. Percy (sometimes spelt Piercy) of Warley Hall, near Birmingham. The young couple took up their residence in that town, where Dr. Percy had been elected physician to the Queen's Hospital. He never entered on any general practice, but made some researches in physiology and pathology, which won for him considerable medical fame.

Percy, however, did not care to follow a medical career, and concurrently with his professional studies and practice, he conducted researches in Mineralogy and Metallurgy, including specially the constitution of crystallised slags. In these researches, which commenced in 1846, he had the co-operation of the late Mr. David Forbes—formerly Secretary to the Iron and Steel Institute—and Professor W. H. Miller of Cambridge. Among the studies which these gentlemen took up, the more prominent were the alloys of Copper with Manganese and Nickel, the effect of Phosphorus on Copper, and the composition and qualities of coal.

In his masterly Presidential Address, well worthy of being read even to-day, contributed to the Iron and Steel Institute in 1885, that is, forty years later, Dr. Percy when referring to the problems connected with the appearance of silica in the slag of iron blast furnaces, and to show his keen delight in matters metallurgical, mentioned that he had recently received what he characterised as "a superb specimen, more valuable to me than a mass of gold of equal weight; the sight of it affords me delight. I often look at this specimen, and every time with increasing pleasure." In 1877 he received the Bessemer Gold Medal of the Iron and Steel Institute.

Speaking personally, I was largely influenced to take up the investigation of Alloys of Iron with other Elements by my study of Percy's books, combined with the splendid work of the Terre Noire Co., France,

on special steels, steel castings, and ferrous alloys, so well illustrated both by their exhibits and literature, at the great Paris Exhibition of 1878.

The fascinating descriptions of the thousand and one experiments carried out by Percy, could not fail to arouse interest and eventually bring to the mind of anyone carefully studying them, the great possibilities of steel alloys. As Faraday's records show, his master mind was also attracted in this same direction. The early studies of these two great men have happily matured to the enormous benefit of the world at large. I consider it a matter of no little satisfaction and encouragement to have worked in this same direction.

Percy resided for eleven years in Birmingham, and it was in this city where he first became interested in Metallurgy, thus obtaining the experience which eventually, in 1851, led to his becoming the Lecturer on Metallurgy at the then newly formed Royal School of Mines, and Metallurgist to the Museum in Jermyn Street, which even to-day stands unrivalled in its wonderful contents relating to Mineralogy. Until that date no Professor of Metallurgy had been selected, though there had long been a crying want for such an appointment in this country, the natural wealth of which depends so much on its mineral resources and a correct understanding of how to win them from Mother Earth as well as to turn them into metals which are so important to meet the needs of modern mankind.

Percy was a man with astonishing energy and great genius. Several of his books are classic ones and even to-day they are most useful for reference. He was lavish in his hospitality and most of his friends were connected with the iron and steel trade. He was much indebted to local iron makers, including Blackwell of Dudley, Dawes of Bromford, and many others, for the data which he obtained and put forward in his books. His classic book *Metallurgy: the Art of extracting Metals from their Ores, and adapting them to various purposes of Manufacture*, was written whilst he was Lecturer on Metallurgy at the Royal School of Mines. The first part was published at the end of 1861, and the second part in February, 1864. In his methodical way he dealt with the physical properties of iron, the mechanical properties of iron, and alloys of iron. He also covered the ground with regard to iron ores and their assay; direct extraction; blast furnace practice; the production of malleable iron from cast iron. Separate chapters were devoted to steel, including the production of steel by the addition of carbon to malleable iron; by partial decarburisation of cast iron; and by fusion of pig iron with malleable iron. He dealt with the casting, the manipulation of steel, also its mechanical qualities.

To my mind, Percy rightly stated that the age of iron preceded the age of bronze. He admitted that there had not been much evidence of this collected, but pointed out that this was largely due to the fact that iron is rapidly corroded by oxidation, even in dry climates; whereas bronze is acted upon but slowly, even in moist climates. As an indirect confirmation of this Sir William Flinders Petrie, F.R.S., to whom I am sure all here present offer heartiest congratulations upon his recent Knighthood for the magnificent work done over such a long period of time in his studies in Egyptology, showed me a few months ago a small dagger shaped knife, which he vouched for as dating back to the VI-VIII Dynasty, about 4000 B.C. But how comparatively few evidences there

Dr. PRIESTLEY'S HOUSE AND LABORATORY, FAIR HILL.
Destroyed in the Riots which took place on July 14th, 1791.

From a Picture sketched on the spot in the possession of Joseph Parkes.

are on this point. The use of steel is attested by the mortuary furniture on many Anglo-Saxon graves. Many tombs of ancient times have revealed specimens of steel. The comparative rarity of the steel is explained by the indifference with which it has been regarded by archæologists. Many steels have been found accompanied by flints, the latter much worn by continued striking, and covered with oxide of iron, showing they had been in full use. These two examples further confirm Dr. Percy's belief as to the position in point of time of the Iron Age. I have dealt with this subject in several papers to our Scientific and Technical Societies, and will be glad to send copies to anyone interested.

Percy gives full credit to Dud Dudley of Tipton, and assigns to him the distinction of having first solved the important economical problem of the extraction of iron from its ores by means of pit coal.

GORE (1826-1908).—We now turn to one who was not a maker of Metallurgical products but whose scientific researches and laboratory work make us much indebted to him; I refer to Dr. George Gore, F.R.S. whose portrait is shown in Plate 10. Though born at Bristol in 1826, he had a long connection with Birmingham. If he had done nothing beyond writing his admirable book *The Art of Scientific Discovery*, he would have made a name for himself by this alone. It is a work which, whilst now out of print and very scarce, well deserves to be re-issued, containing as it does such excellent precepts and guidance to those engaged in research work, whether purely scientific or technical. They apply to-day just as much as when he wrote them forty-five years ago.

I once lent a copy to my friend, the late Sir William Osler, F.R.S., who was so fascinated with its contents that he humorously wrote refusing most positively to return the book until another one had been procured for himself. I was delighted with his interest in this wonderful work, and after much trouble was finally successful in obtaining a copy for him.

Such importance do I attach to Gore's views and advice, that in the Appendix of this Address there is given a full extract of the views he expressed, in 1878, on the general conditions and methods of research in Physics and Chemistry.

The guidance there set forth should make the book be read by all younger men studying and engaged in research questions.

Gore left school at thirteen years of age and began work as an errand boy. At seventeen he was apprenticed to a cooper, and worked at that trade until he was twenty-one, meanwhile studying Science and making what experiments he could in his small leisure.

He was keenly interested in electro-deposition, and probably his desire to pursue this subject is the reason why he came to Birmingham in 1851. He held classes on electro-plating and chemistry, and thus began his long career as a teacher in Birmingham. Later, he was appointed Science Master at King Edward's School, a post which he held for many years.

Gore was also an ardent advocate of research. His well-known works on *The Scientific Bases of Morality; The New Scientific System of Morality; The Scientific Bases of National Progress*, and *The Art of Scientific Discovery* are of the highest importance. Finally, in 1880, an "Institute of Scientific Research" was founded by a few citizens in

Birmingham ; here Dr. Gore was installed, and worked for the rest of his life.

He was elected a Fellow of the Royal Society in 1865 ; in 1877, received the degree of LL.D. from the University of Edinburgh ; and in 1891 he was given a Civil List Pension in recognition of his contributions to Science. He died on December 20th, 1908, when nearly eighty-three years of age. By his will his residuary estate was equally divided between the Royal Society and the Royal Institution for the purpose of assisting original scientific discovery. The share of the Royal Society, amounting to nearly £2,500, has been invested as the Gore Fund.

In a Paper on "A Momentary Molecular Change in Iron Wire," published in the Proceedings of the Royal Society, No. 108, p. 260, January 28th, 1869, Gore described a singular phenomenon which he observed in the cooling of iron wire whilst searching for magneto-electric induction by sudden change of temperature of a magnet. The wire had been heated to a full redness whilst kept under a suitable degree of longitudinal tension by means of a spring attached to one of its ends. During cooling, and whilst still red hot, the iron gradually diminished in length, then suddenly elongated by diminution of cohesion, and finally contracted gradually, almost to its original length, during the remainder of the cooling process. A corresponding but reverse phenomenon did not occur during the process of heating the wire. Various other metals were similarly examined, but no such peculiar phenomenon was found.

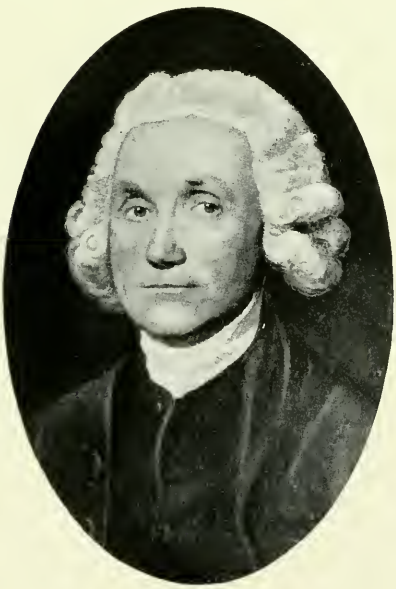
In another interesting paper, "On the Molecular and Magnetic Changes of Iron, etc. at different temperatures," which appeared in the *Philosophical Magazine*, Vol. xl, July-December, 1870, he stated: "Mr. R. W. Fox (*Phil. Mag.* 1835, Vol. ii, p. 388) showed that cast iron in the melted state produces little or no effect upon a delicately poised magnetic needle placed near it during its cooling, solidification and subsequent further cooling, until the solid metal acquires 'a cherry-red colour'; it then suddenly attracts the needle with great energy." Gilbert had many years before shown that a piece of soft iron at a bright red heat loses all ordinary signs of magnetism ; and Faraday had demonstrated that wrought iron retains only traces of its ordinary magnetic capacity at that temperature.

He concluded the particular research mentioned above by saying : "The changes produced by heat in even so simple a substance as iron were so numerous in some of these experiments as to produce the impression that the metal was endowed with vitality."

Gore carried out many valuable series of experiments which are well worth consideration even to-day, specially on account of the wonderful power of observation he displayed, but there is no space in an Address of this kind to do more than briefly refer to them.

Out of Gore's experiments sprung the still more important ones of Barrett, who discovered the property of recalescence in steel. These were further elaborated by the late Professor F. Osmond, the late Sir William Roberts-Austen, Professor H. le Chatelier, Dr. J. E. Stead, Professor J. O. Arnold, Dr. W. Rosenhain, Professor H. C. H. Carpenter, and others. From this combined research work have developed many remarkable applications to the Metallurgy of iron and steel. Other metals, with the exception of nickel and cobalt, show very little change under heating and cooling ; and the changes which do

MATTHEW BOULTON, F.R.S.
(1728-1809)



JOSEPH PRIESTLEY, F.R.S.
(1733-1804)

occur in these two metals are in no way so pronounced as in iron.

SIEMENS (1823-1883).—Siemens first visited England about 1842 in connection with a new Electric Process of Gilding and Silvering. His success on that occasion, when having been paid a considerable sum by Messrs. Elkington he was able to return home a comparative Crœsus, led to a second visit and a further receipt of £1,200. This took place in the spring of 1844 and from that time England became his home.

As is well known, Siemens did his most notable work in practical Electricity and the application of heat to Industrial Processes. In 1853 he read a Paper to the Institution of Civil Engineers " On the Conversion of Heat into Mechanical Effect." Sir Dugald Clerk, F.R.S., has gone so far as to say : " Here for the first time we find the engineer guided by an intelligible principle, and that of all the engineers who spoke on that occasion, Siemens alone seemed to thoroughly apprehend the value of Joule's results." Sir William Siemens' knowledge of scientific principles enabled him to grasp the importance of the invention of the Regenerative Furnace by his brother, Mr. Friedrich Siemens. This invention was made in 1856. Experiments made with the Furnace were speedily followed by a practical application, notably at the glass works of Messrs. Chance in Birmingham.

It was in 1861 that the two brothers patented their Gas Producer for use in conjunction with the Regenerative Furnace.

The Siemens Steel Works were started in Birmingham in 1866, and two years later the Landore Siemens Steel Company began work at Swansea. This is specially mentioned because it was from the Landore Works that Siemens supplied the material for the first of our steel built Men-of-War, H.M.S. *Iris* and *Mercury*. It will be remembered that Sir Nathaniel Barnaby asked the Steel Makers of Great Britain to produce a steel of remarkable quality for shipbuilding purposes.

One result of the success of this great development by Siemens was the rapid extension of the use of steel for shipbuilding. Prior to 1877 only 1 per cent. of our ships were built of steel, but at the time of Siemens' death, only six years later, the proportion had risen to 14 per cent., and as you all know, by the end of the century, practically every ship was of steel.

Sir William Siemens, F.R.S., received the Bessemer Gold Medal of the Iron and Steel Institute in 1875, and was also President of that body from 1877 to 1879.

GREENWOOD (1846-1905).—Professor W. H. Greenwood, who was born at Manchester and received his Scientific training at the Owens College there, and at the Royal School of Mines and University College, London, came to Birmingham in 1885 and for many years held a most important position with the Birmingham Small Arms and Metal Co. In 1869 he obtained a Senior Whitworth Scholarship, and became Assistant Manager at the Whitworth Works in Manchester in 1871. He went to Russia in 1875 as Chief Engineer to the Government Ordnance Works at Obouchoff, near St. Petersburg. On returning to England, in 1880, he became connected with the Landore Siemens Steel Co. and five years later accepted the Professorship of Mechanical Engineering and Metallurgy in the University College, Sheffield, that is before the foundation of the University. His Manual on Metallurgy

and numerous papers are well known and of great interest in this particular branch of Science.

KAPP (1852-1922).—An account of those who have so greatly helped Scientific Training and Research in Birmingham would not be complete without a reference to the late Professor Kapp who was the first Professor of Electrical Engineering in the University from 1909 to 1919. I was fortunate enough to have the pleasure of knowing him, not intimately, but through important correspondence which passed between us.

To quote from that excellent magazine of your University, *The Mermaid*: " Kapp was no mere Commercial Engineer, but a forceful and resolute real-presence, not afraid of declaring that which in the real soul of him he feels to be true. A rugged and even despotic temperament, impatient of triflers; yet withal that greatest of God's creatures—a sincere man. To carry out the ideal of his work he wore himself out, but meanwhile endowed some of his students, his books, and his inventions with his own life."

OTHER NAMES.—The pioneers already mentioned by no means exhaust the list of great men who have been associated with this city. If space had permitted, there is much that might be said concerning John Bright and Joseph Chamberlain—men who belong to the Empire and were two of its great builders; Josiah Mason, to whose great interest in education Birmingham owes so much. George Elkington, whose important work has been so well described by Mr. R. E. Leader of Sheffield, in an interesting Paper entitled: " The Early History of Electro Silver Plating," read before the Institute of Metals in September, 1919; also Philip Henry Muntz, G. Dawson, the Tangyes, the Kenricks, and many others.

I should have liked to include the name of the late Mr. J. D. Ellis as a Birmingham man. He however left the city in 1854 for Sheffield, where he made a name famous in the annals of Metallurgy and its developments. By his encouragement of scientific methods and research, his son, Sir William Ellis, G.B.E., the President Elect of the Iron and Steel Institute for next year, is worthily continuing his father's work.

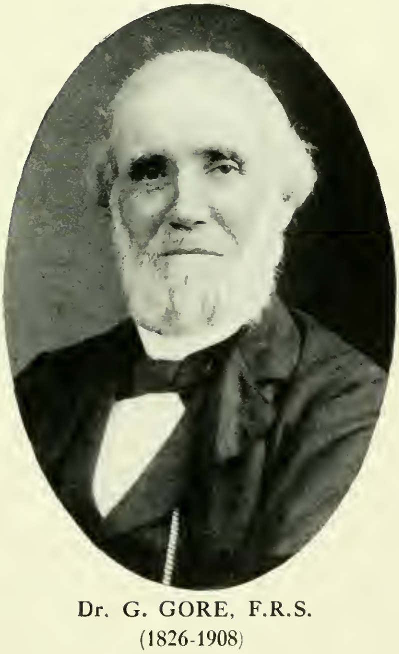
PROMINENT BIRMINGHAM MEN OF THE PRESENT DAY

Having reviewed the work of Birmingham men of the past, reference may now be made to some of those of the present day. For want of space it is not possible to give here the names of all those deserving of mention, or of those whose work does not come within the scope of this Address. Other living authorities too, are mentioned in the section devoted to your University.

Naturally one of the first names in our minds is that of Sir Oliver Lodge, D.Sc., LL.D., F.R.S., whose portrait is given in Plate 11. Though not a native of Birmingham he was born not far away, at Stoke-on-Trent, in 1851, and laboured long and successfully in your midst to the great advantage of your University and your city generally.

He is a wonderful example of one who, although brought up under an ordinary Grammar School Education, was able finally to reach the greatest heights, not only in the world of science but also in administrative ability on educational matters. It is not necessary in Birmingham to speak in detail of Sir Oliver's great work, which would occupy not a few paragraphs, but many pages.

Dr. JOHN PERCY, F.R.S.
(1817-1889)



Dr. G. GORE, F.R.S.
(1826-1908)

In 1919 I had the pleasure of seeing him receive at the hands of H.R.H. The Duke of Connaught, the Albert Gold Medal of the Royal Society of Arts, one of the highest honours bestowed in this Country and one he so well deserved.

It is perhaps not so generally known as it should be, how important has been the part played by Sir Oliver Lodge in the early development of Wireless Telegraphy. The following reference, taken from a Biographical Sketch by " J.H.P." circulated some time ago by Messrs. Cornish Bros. Ltd., of Birmingham, may therefore be of interest:

"One very remarkable experiment is now well-known under the name of Lodge's Resonating experiment with the electro-magnetic waves in air discovered by Hertz in 1888, and there can be no doubt that if Hertz had not made the discovery we should very soon have learned it from Lodge. Indeed, Hertz himself says: 'Professor Oliver Lodge, in Liverpool, investigated the theory of the lightning-conductor, and in connection with this carried out a series of experiments on the discharge of small condensers, which led him on to the observation of oscillations and waves in wires. Inasmuch as he entirely accepted Maxwell's views, and eagerly strove to verify them, there can scarcely be any doubt that if I had not anticipated him he would also have succeeded in obtaining waves in the air, and thus also in proving the propagation with time of electric force.' Prepared by his own researches, Lodge at once recognised the immense importance of Hertz's discovery, and through him and through Fitzgerald the knowledge of it was rapidly spread in this country. It was no doubt largely due to British appreciation that the value of Hertz's work, and of the theory of Maxwell which inspired it, was recognised so soon in Germany.

"In the earliest years of investigation of electro-magnetic waves Lodge was ever to the fore, devising modes of creating and detecting the waves, investigating their properties, writing papers, giving lectures, and spreading far and wide a knowledge of the new wonder. Among his most brilliant discoveries was that of the 'coherer' for detecting the waves. With this detector he devised the first practical wireless telegraph, sending signals over a distance of several hundred yards.

"This was all pioneer work, done before Marconi took up the subject, and Marconi undoubtedly built upon the foundation which Lodge had laid.

"Whatever developments and changes may be made in the system of wireless telegraphy, there can be no doubt that Sir Oliver Lodge will always be recognised as one of the founders of the system, as a pioneer in researches upon which others have built."

Quite recently Sir Oliver was kind enough to open two new Laboratories in the Applied Science Department of our Sheffield University, when he gave one of his characteristic and instructive addresses, which was greatly appreciated.

Birmingham is indeed greatly indebted to Sir Oliver Lodge for all that he has done. May he long be spared to continue his work.

Amongst other Birmingham men of note in the World of Science of to-day is Dr. F. W. Aston, F.R.S., who only last year was awarded the great and much-prized distinction of the Nobel Prize. Dr. Aston graduated as B.Sc. from Birmingham, and was on the Staff of the late Professor Poynting. Before his association with Sir J. J. Thomson, P.P.R.S., he obtained his D.Sc. in Birmingham, and his Research Fellowship at Trinity College, Cambridge.

I am glad to see that he will deliver the Hay lecture of the Institute of Metals on "Atoms and Isotopes" before the British Empire Mining and Metallurgical Congress next year.

Professor Aston's paper on "Atomic Weights and Isotopes," as given in Lectures before the Franklin Institute of Philadelphia in March, 1922, is a most fascinating one and ought to be read by all those studying or interested in Chemistry or Physics.

In these Lectures Professor Aston brings before our minds probably more clearly than anyone else, what is meant by the atom. I am therefore led to refer to some of his more interesting statements and to quote them freely. Concerning the atomic structure of matter, he says that matter is discontinuous and consists of discrete particles is now an accepted fact, but it is by no means obvious to the senses. The surfaces of clean liquids, even under the most powerful microscope, appear perfectly smooth, coherent and continuous. The merest trace of soluble dye will colour millions of times its volume of water. It is not surprising therefore that in the past there have arisen schools who believed that matter was quite continuous and infinitely divisible.

The upholders of this view said that if you took a piece of material, lead, for instance, and went on cutting it into smaller and smaller fragments with a sufficiently sharp knife, you could go on indefinitely. The opposing school argued that at some stage in the operations either the act of section would become impossible or the result would be lead no longer. Bacon, Descartes, Gassendi, Boyle and Hooke were all partial to the latter theory, and Newton, in 1675, tried to explain Boyle's Law on the assumption that gases were made up of mutually repulsive particles.

Going on to consider the figures expressing the number of atoms in an ordinary mass of material, Aston says that the mind is staggered by their immensity. Just as an illustration, applying his method of sub-division into cubes, any vivid notion of the size of the cubes passes out of our power at about the twelfth sub-division. Thus, if we slice a decimeter cube into square plates one atom thick the area of these plates will total one and one-quarter square miles. If we cut these plates into strings of atoms spaced apart as they are in the solid, these decimeter strings put end to end will reach 6.3 million million miles, the distance light will travel in a year, a quarter of the distance to the nearest fixed star. If the atoms are spaced but one millimeter apart the string will be three and a half million times longer yet, spanning the whole known universe.

Again, if an ordinary evacuated electric light bulb were pierced with an aperture such that one million molecules of air entered per second, the pressure in the bulb would not rise to that of the air outside for a hundred million years. Perhaps the most striking illustration is as follows: Take a tumbler of water and—supposing it possible—label all the molecules in it. Throw the water into the sea, or indeed, anywhere you please, and after a period of time so great that all the water on the earth—in sea, lakes, rivers, and clouds—has had time to become perfectly mixed, fill your tumbler again at the nearest tap. How many of the labelled molecules are to be expected in it? The answer is roughly 2,000; for although the number of tumblers full of water on the earth is 5×10^{21} the number of molecules of water in a single tumbler is 10^{25}.

From the foregoing can be grasped the immensity of the problem with which we are faced. It would appear absurd to hope to obtain effects from single atoms, but as Professor Aston points out, this can now be done in several ways. In fact it is largely due to the results of experiments in this direction that the foregoing figures can be stated with so much confidence.

It is not possible to go into the subject fully here, but Birmingham should indeed be proud to have one come from their midst who is helping so materially to solve a problem which, without doubt, in the not far distant future will intimately concern the welfare of the inhabitants of this world of ours.

As further showing the practical bearing of the work upon which Professor Aston has been engaged, and the clear manner in which he has been able to bring together the researches of various scientists, I quote from him once more when he says: Take the case of one gram atom of hydrogen; that is to say, the quantity of hydrogen in 9 c.c. of water. If this is entirely transformed into helium the energy liberated will be $.0077 \times 9 \times 10^{20} = 6.93 \times 10^{18}$ ergs. Expressed in terms of heat this is 1.66×10^{11} calories, or in terms of work 200,000 kilowatt hours. We have here at last a source of energy sufficient to account for the heat of the sun. In this connection Eddington remarks that if only 10 per cent of the total hydrogen on the sun were transformed into helium enough energy would be liberated to maintain its present radiation for a thousand million years.

Should the research worker of the future discover some means of releasing this energy in a form which could be employed, the human race will have at its command powers beyond the dreams of scientific fiction, but the remote possibility must always be considered that the energy once liberated will be completely uncontrollable and by its intense violence detonate all neighbouring substances. In this event the whole of the hydrogen on the earth might be transformed at once and the success of the experiment published to the universe at large by our emergence as a new star!

In addition to the foregoing names, reference may be made, amongst others, to Sir Gerard A. Muntz, Bt., Past President of the Institute of Metals, who has done so much to assist the Metallurgy of Non-Ferrous Metals; Sir George W. Kenrick, Chairman of the City of Birmingham Education Committee; Alderman W. A. Cadbury, J.P.; Sir Charles Hyde; Sir Hallewell Rogers; Mr. G. C. Vyle; Alderman J. H. Lloyd; Mr. F. Dudley Docker; Mr. W. Tangye; Sir Edward Manville: Mr. H. James Yates, and many others.

Reference should also be made to the most excellent work of Dr. J. Newton Friend, head of the Chemistry Department of the Municipal Technical School, Birmingham, Scientific Adviser to the Corrosion Committee of the Institution of Civil Engineers, and Examiner in Chemistry for the same Institution. Dr. Friend received, in 1913, the Carnegie Gold Medal from the Iron and Steel Institute for his researches on Corrosion, on which subject he has built up a well-deserved reputation. I wish Dr. Friend every success in the enlarged scope of his work now to be undertaken in his new Lecture Room and Research Laboratory. The latter I understand is to be devoted mainly to Corrosion Research.

Section III

Birmingham University

Foundation and Development.—In an article on "The Birmingham University," by Professor C. Alfred Smith, M.Sc., M.I.Mech.E., which appeared in *Engineering* in 1906, it was mentioned that the beginning of higher education in the Midlands, including both scientific and technical education, was marked by the opening of the Mason Science College at Birmingham by Huxley in 1880. This building forms part of the Chamberlain Square, which contains the Town Hall, Free Library, Art Galleries and Municipal Council House. Also alongside is the statue of Sir Josiah Mason, one of Birmingham's great citizens, who founded the College.

It was in 1898 that Mr. Joseph Chamberlain publicly announced the idea of a Birmingham or a Midland University, as some have termed it, and about the same time Mr. Andrew Carnegie forwarded a munificent donation of £50,000, accompanied by his usual practical advice that, before anything was done in Birmingham, it would be advisable for the Council to ascertain what was taking place in the United States.

A special deputation was therefore sent some four years before the Moseley Educational Commission was despatched on its famous tour of inspection over the same ground.

Dr. now Sir Oliver Lodge, was appointed Principal of the University, and amongst the Professors were Drs. Poynting, Bridge, Lapworth, also Sir William Tilden, F.R.S., who has done so much for the Science of Chemistry.

Then followed the erection, on a site of some 25 acres, of the present University known as the new Bournbrook Building, where this Lecture is being delivered.

It was largely the foresight of that great Englishman, Mr. Joseph Chamberlain, which enabled Birmingham to take up the University scheme, and later on he well said "We have built for posterity."

High as is your Chamberlain Tower—some 325 feet—surpassingly higher in the minds of his countrymen was this great Englishman himself.

Leading Men.—Amongst those controlling the affairs of the University at the present time are Lord Robert Cecil, Chancellor; Sir Gilbert Barling, Bt., C.B., Vice-Chancellor; Mr. C. Grant Robertson, M.A., C.V.O., Principal of the University, Chairman of the University Research Board; Sir William Ashley, Ph.D., M.Comm., M.A., Vice-Principal of the University and Dean of the Faculty of Commerce; Professor F. W. Burstall, M.A., Dean of the Faculty of Science; Professor F. C. Lea, Civil Engineering; Professor Thomas Turner,

SIR OLIVER LODGE, F.R.S.
Formerly Principal of the University.

Mr. C. GRANT ROBERTSON, M.A., C.V.O.
The Present Principal of the University.

Metallurgy; Professor F. W. Gamble, Mason Professor of Zoology and Comparative Anatomy; Dr. G. T. Morgan, Professor of Chemistry, who holds the office previously occupied by Professor P. Frankland, F.R.S.; Professor S. W. J. Smith, Professor of Physics; Dr. G. N. Watson, Professor of Mathematics; and Mr. G. H. Morley, Secretary, to whom I am indebted for information on the subject of your University.

I do not of course refer to the individual work of all the eminent men forming the University, that is, outside those branches of knowledge with which I am dealing in this Address.

I would, however, mention Mr. Charles Grant Robertson, C.V.O., M.A., whose portrait is shown in Plate 11, the Principal of the University since 1920. In view of his many successes at Oxford, and his historical studies which are of the highest order, Birmingham University is to be heartily congratulated in having obtained his guidance and help.

There is also the important work of Sir William Ashley, Vice-Principal and Professor of Commerce since 1901, who whilst neither an Engineer nor a Metallurgist, has rendered great service to our country in connection with his studies of Economics, which so intimately concern Commerce and Industry. His many contributions are valued most highly; long may he continue his good work.

In this respect I call attention to the great work being done by the London School of Economics and Political Science, with its able Director, Sir William Beveridge. The true way to fight and conquer Bolshevism and Communistic heresies, for they are nothing less, is by increasing knowledge in this branch of human thought. Our British Labour Party in the main happily seems to understand this, at any rate most of their Leaders do. Such study is the true safety valve in our National Education, and in this respect I think we differ from all other Nations.

It may be added that in the London School of Economics mentioned, there are no less than sixty-one Professors, Readers, and Lecturers on the Staff of the School, with eighteen Tutors, Assistant Lecturers, and Assistants, and more than forty separate subjects are dealt with.

The subjects of the courses amount to more than two hundred, comprising:

Economics.—Economics, Descriptive Economics, Economic Theory, Economic History, Economics of Russia, Economics of India.

Statistics.—Statistics, Mathematics, Mathematics and Statistics, Statistics and Library.

Commerce.—Commerce, Accountancy and Banking Methods, Transport, Shipping, Accounting, Costing, Industrial.

Geography.—Geography, Geography and Commerce, Commercial Geography.

Languages.—English, French, German.

Law.—Law, Commercial and Industrial Law, International Law, Constitutional Law, Railway Law, Mercantile Law, Industrial Law.

Sociology.—Sociology, Social Science and Administration, Social Anthropology, Welfare Work, Industrial Psychology, Ethnology, Physiology.

History.—History, French History and Institutions, History and Public Administration.

Politics.—Political Science, Politics and Public Administration, Public Administration, Public Finance, Comparative Administration.

Another member of the University is Professor F. M. Dixon, M.A., M.Inst.C.E., who has done most excellent work. The great assistance he rendered to Sir Henry Fowler, Director of Production in the Ministry of Munitions during the War, is well known and appreciated by his countrymen.

Professor S. W. J. Smith, M.A., D.Sc., F.R.S., Professor of Physics, has to his credit publications and papers on Electricity and Magnetism which are highly appreciated. He is being assisted by Mr. A. A. Dee, who for several years rendered me excellent service and assistance. In June last he submitted to the Royal Society, through Professor Smith, a paper on "The Effect of Quenching from above the Carbide Transition Temperature upon the Magnetism of Steel."

The important work of Professors Burstall and Turner is referred to in the later sections of this Address.

It has recently been announced that amongst the musical studies to be taken up at the University is that of bell ringing, this being due to the initiative of Professor Granville Bantock. Apparently students of Campanology have hitherto been overlooked. The subject will be included in the Acoustics Courses and lectures will be given on bells and bell music by the eminent authority Mr. Starmer. A special collection of bells is being made for the purpose of demonstration and practice.

It will be noticed that reference is made in Section VI of this Address to the constitution of the proposed "Museaum Minervæ" in 1636, which included a Professor of Music who was to teach skill in singing and music, to play upon the Organ, Lute, Violl and other instruments.

In one of the departments of the Great International Exhibition at Paris in 1878, the pleasing effects obtained on quite a large scale from musical chimes still remain in my memory.

The University is to be congratulated upon having taken up educational work in this direction.

In view of the researches carried out by Professor F. C. Lea of the Department of Civil Engineering with regard to the testing and utilisation of Metallurgical products, a brief reference may be made to some of his important work. His contributions amount to about thirty papers, many of them of important character, read before the Royal Society, the Institution of Civil Engineers, from whom he received the Telford Premium, the Institution of Mechanical Engineers, the British Association, and other scientific and technical bodies. During the War he was a member of several special committees, and carried out much useful research work in connection with rigid airships, aeroplane structures and aeroplane engines. His long experience, before coming to Birmingham, as chief assistant to Professor Unwin and Professor Dalby at the City and Guilds Engineering College, has been most valuable.

Special reference should be made to the famous 300-ton testing machine in Professor Lea's Department, indeed a giant among testing machines. It is capable of pulling a tensile test bar of $3\frac{1}{2}''$ diameter and $3'\ 6''$ in length, and can also be used for compression and bending tests of beams. Owing to its large loading capacity it proved most useful during the war in connection with aircraft work. The machine,

it is interesting to know, was made by Messrs. Avery of Birmingham, who have recently completed a similar large impact machine of special design for testing Railway Couplers.

PROGRESS.—As regards the progress of this great University, whose motto "Per ardua ad alta" is much to be admired, it may be interesting to state that last Session the students numbered 1,924 of whom 439 were Matriculated students, practically the same as in the previous year. In the Faculty of Science there were 768 students, about 430 degrees being conferred in 1921-1922. These are indeed satisfactory results, in view of the difficult nature of the times.

The general endowments of the University are £849,000, the Special Endowments—Chairs, Lectureships, Scholarships, £336,000. It is pleasing to note that under the heading of "debt" is found the satisfactory word "*none*."

In 1921-1922 there was expended the sum of about £176,000, and the students' fees amounted to more than one-fourth of this total. Thus as an approximate estimate it may be stated that on your population, roughly one million, this works out at about thirty-two pence per head after making the allowance just mentioned. When all the advantages derived are considered the investment is indeed a cheap one. Imagine for one moment all these facilities taken away—Birmingham would be left in Cimmerian Darkness. As the result mentioned represents generally the condition now prevailing in our country, we can congratulate ourselves upon the wonderful advance made during about the last thirty years. It is marvellous how we ever got on without these facilities in what may be termed those pre-educational times.

I do not know what were the costs or receipts of the Metallurgical Section, but I notice that the stipends represent the modest sum of £2,100, which with £1,000 for the apparatus and wages represents a total of £3,000.

Knowing the high quality of the work turned out by the Head of this Department, Professor T. Turner, who has toiled for some forty years on your behalf, here again it can well be said that Birmingham is to be heartily congratulated upon this section of her University work.

NUMBER OF UNIVERSITIES AND COLLEGES.—Whilst referring to University work it may be interesting to mention that in my Presidential Address to the Society of British Gas Industries, under the section devoted to Education, I pointed out that in our Empire, including the British Isles, Commonwealths, Dominions and Colonies, there are 60 Universities, 233 Colleges, and 44 Technical Schools. These numbers compare with 98 Universities and 16 Technical Schools in the United States. France has 16 Universities, Italy 22 Universities, Austria-Hungary 11, and Germany possessed 21 before the War.

As regards the teaching staff in the Universities, including the Heads, Professors, Lecturers, Demonstrators, and Trained Assistants, it is believed that there are not far short of 10,000 in the British Empire.

SECTION IV

The Birmingham University Metallurgical Society

BIRMINGHAM UNIVERSITY METALLURGICAL SOCIETY.—I feel sure that you will pardon me for introducing into this Address two brief personal references, one to myself and the other to my friend of long standing, Professor Thomas Turner, M.Sc., A.R.S.M., F.I.C., whose portrait is shown in Plate 12.

I will first refer to Professor Turner who for many years has been Feeney Professor of Metallurgy at the University of Birmingham, and is President-elect of that important Society the Institute of Metals. He has been President of your Metallurgical Society since it was founded in 1905, when the membership was only nineteen as compared with over one hundred and fifty to-day.

THE THOMAS TURNER PRIZE FOR METALLURGY

As you all know, about three years ago a generous Birmingham manufacturer presented a sum of money with the object of founding the Thomas Turner Prizes for Metallurgy, namely, a Gold Medal, a Bronze Medal, and a Book Prize. These were intended to commemorate the important work done by Professor Turner in Metallurgy, and particularly that in reference to the effect of Silicon upon Cast Iron.

I have known Professor Turner and studied the various Research, Educational and other work he has carried on for some 35 years with results so highly appreciated by all of us for their great merit and worth. A more true and faithful worker in the cause of Metallurgy does not exist. Professor Turner was elected a Member of the Iron and Steel Institute in 1887, before which Society he read papers on "Alloys of Iron and Silicon" in 1889, and "Aluminium Steel" in 1890. His book on *The Metallurgy of Iron* was written in 1895. He also carried out most useful research work on hardness determinations and contributed valuable papers on this subject when introducing his Sclerometer, which had a diamond point with a weight and a graduated lever, and on it a scale of about one hundred divisions. This fulfilled the purpose at the time for the particular object its designer had in view.

Professor Turner was occupied in his researches as to the effect of Silicon upon Cast Iron just about the same time that I was engaged in working out my invention of Manganese Steel. I am glad to think that both those investigations were carried out with but one thought in mind, that is, to increase general knowledge, and I trust that the results obtained have shown that this aim has been achieved.

Whilst speaking of the work of Professor Turner it is interesting

PROFESSOR THOMAS TURNER, M.Sc., A.R.S.M., F.I.C.

President of the Birmingham University Metallurgical Society; also President-elect of the Institute of Metals, with which, since 1908, he has been associated as one of its Founders.

to recall that amongst those who have been Students and worked under him in the Metallurgical Department of the old Mason College, were our Prime Minister, the Rt. Hon. Stanley Baldwin, also the Rt. Hon. Neville Chamberlain.

Mr. Baldwin was interested in his father's business near Stourport, and the fact just mentioned shows how desirous he was to equip and qualify himself as a Scientific Metallurgist.

As regards Mr. Neville Chamberlain, he was for some time connected with the well-known Birmingham firm, Elliott's Metal Company, at Selly Oak, and other metallurgical enterprises.

I also heartily congratulate Birmingham on the fact that Mr. Neville Chamberlain is now Chancellor of the Exchequer. I am sure we all wish him every success in this difficult post, and in the handling of the many intricate problems which come before him in connection with the serious responsibilities of his office.

Two other well-known men have been students of metallurgy under Professor Turner, one being Sir Henry Fowler, K.B.E., whose knowledge and skill were of such great service to the Nation during the War. I can truthfully say that the National Factory my firm then erected representing an expenditure of some three-quarters of a million pounds would not have been completed at such an early date, that is in only ten months, but for Sir Henry's help. His untiring energy at the present time on behalf of Engineering and the education of the Engineer are greatly to be admired. His Address as President of Section G, Engineering, at the recent Meeting of the British Association in Liverpool, on " Transport and its Indebtedness to Science " is not only interesting, but a most valuable contribution and ought to be read by all those concerned.

The second student referred to and well known to most of us was Professor McWilliam, who has alas passed away. He served for two years under Professor Turner, and was County Lecturer in Metallurgy at Stafford before he came to Sheffield to work under Professor Arnold.

Mr. G. Shaw Scott, the able Secretary of the Institute of Metals, took his Metallurgical Course under Professor Turner, and was Birmingham's first Graduate in Metallurgy.

Turning now to the second personal reference, which concerns myself, to my surprise on June 20th last I received from Mr. J. H. Costain, your Registrar, the gratifying intimation that the first award of the Thomas Turner Gold Medal had unanimously been made to me as a mark of appreciation of the work I had done in Metallurgy. To be the first to receive this distinction is indeed a great honour, still more that this award should be associated with the name of my friend, Professor Turner, with whom I have had uninterrupted friendship for something like 25 years, and from whose work on behalf of Metallurgy I have greatly profited. In both public and private discussions I cannot remember an unkind or unpleasant word having passed between Professor Turner and myself, even during the most strenuous arguments. Long may his success continue in the important post he occupies. We all owe him a deep debt of gratitude for his painstaking and accurate work on behalf of the branch of Science known as Metallurgy.

I also offer best wishes for the future success in his career to Professor Turner's son, Mr. T. Henry Turner, M.Sc., who is worthily following in his father's footsteps.

Speaking further with regard to the constitution and working of the Birmingham University Metallurgical Society, may I add that the Chairman, who is elected annually, is at present Mr. W. K. McMillan, and the Secretary Mr. D. W. Clarry, to whom I express my best thanks for the useful information he has been kind enough to furnish regarding the Society and its work.

The Society is also greatly indebted to Mr. May, now President of the Guild of Undergraduates, and to Mr. Wharton, last year's Chairman and Secretary, for the large amount of work they have done on its behalf, particularly in arranging the first Inter-University Metallurgical Conference.

It is to be noted with interest that Delegates of the Society went to Germany in the Easter vacation, and that about twenty-five members spent three weeks in that country, visiting Hamburg, Hanover, Brunswick, Berlin and Upper Silesia.

TECHNICAL SOCIETIES, RESEARCH AND TRADE ASSOCIATIONS IN BIRMINGHAM

STAFFORDSHIRE IRON AND STEEL INSTITUTE.—As regards local technical associations, I would refer to the excellent work carried out by the Staffordshire Iron and Steel Institute, which was founded in 1866. Amongst its past Presidents are Mr. William Lester, who first filled the Chair, Professor Turner, and the late Professor H. le Neve Foster. Its present President is Mr. F. J. Cook, who by this position also occupies a place of honour as Member of Council of the Iron and Steel Institute.

ASSOCIATION OF DROP FORGERS.—There is also the important Association of Drop Forgers and Stampers in Birmingham, where this business is conducted on a large scale.

BRITISH CAST IRON RESEARCH ASSOCIATION.—We all regret the retirement on account of ill health of Dr. Percy Longmuir from the Directorship of the British Cast Iron Research Association, and we trust that his ill health is only a temporary matter. Mr. Thomas Vickers is the Secretary.

BRITISH NON-FERROUS METALS RESEARCH ASSOCIATION.—Dr. R. S. Hutton, who has had an exceptionally varied experience in scientific research and industry, is the Director and Secretary of the British Non-Ferrous Metals Research Association, which has its central office in Birmingham.

The Birmingham University has throughout been closely connected with the work of the Association, and has had its researches carried out in the Metallurgical Department under the supervision of Professor Turner.

The recent progress in the support of the Association by firms in Birmingham and elsewhere is remarkable, and the programme of its researches includes several subjects which under the special circumstances attending this branch of industry could scarcely be attacked otherwise than by such co-operative effort.

BIRMINGHAM METALLURGICAL SOCIETY.—Another important organisation is the Birmingham Metallurgical Society, founded in 1903, and incorporated in 1920, whose President for this Session is Mr. Harold W. Jacks, and the Secretary Mr. A. C. Craig. Its membership during

the War was close upon 1,000 and is now about 600. Amongst the past Presidents have been Professor T. Turner, who has occupied the Chair in seven different years, Mr. Lantsberry, and the late Mr. A. H. Hiorns, who had much to do with the founding of the Society and whose efforts on behalf of science were much appreciated.

The work of the Society covers both Ferrous and Non-Ferrous Metallurgy, as also other subjects of a kindred nature.

A Prize of five guineas and a Bronze Medal is offered every year for a thesis of Metallurgical interest by a student of the technical schools in the Midlands. Papers of considerable merit have been submitted in connection with this scheme.

The Iron and Steel Institute.—When speaking of technical societies devoted to Metallurgy, it may well be said that Birmingham has fully performed its share of educational work in this direction. Our leading technical body, as regards those interested in Metallurgy, is the Iron and Steel Institute, founded in 1870, with the Duke of Devonshire as its first President, and afterwards followed by a long and illustrious line of Presidents, including one American, one Frenchman, and one Belgian, for we are a cosmopolitan body. This Institute is represented in the Birmingham District by 51 Members, Staffordshire has 55, and Shropshire and Warwickshire 33 Members, that is a grand total of 139 for the district.

Mr. G. Hatton, C.B.E., Brierley Hill, Staffordshire, is a Member of Council of the Institute, as well as Mr. F. J. Cook, President of the Staffordshire Iron and Steel Institute, both of whom by their help and encouragement have rendered great service to Metallurgy.

The Iron and Steel Institute has never yet had a Birmingham born man as President, although Dr. Percy who lived so long in your city occupied the Chair in 1895. I hope, however, that this may occur before long, as your city is more than entitled to the honour. Mr. Arthur Keen, so well known to most of us, was for many years a Member of Council of the Institute, and had he lived would undoubtedly have filled this position.

At the Iron and Steel Institute Meeting in Birmingham, 1895, with Sir David Dale as President, Sir Benjamin Hingley, Bart., the Chairman of the Reception Committee, described your city as being "the great centre, the metropolis of the iron industry and of metalliferous work in England." Mr. Arthur Keen was Treasurer of the Local Reception Committee.

One of the papers then read was on "The Iron Industry of South Staffordshire" by Mr. Daniel Jones, F.G.S., Secretary of the South Staffordshire Ironmasters' Association, who gave the graphic description, already quoted, of the appearance of this district about the middle of last century, when furnace gases were allowed to burn wastefully in the open air.

At this same meeting I read a paper on the "Production of Iron by a New Process." I obtained direct from the oxide an iron containing only .03% C. Although this related to comparatively small laboratory experiments there were then outlined methods of producing pure metals which have since been adopted on a commercial scale.

Associateship of the Iron and Steel Institute.—There is one point I wish specially to mention this evening, and that is, each member of this Society should sooner or later join one of the great Technical

Institutions, whether Civil, Mechanical, Electrical, or Metallurgical. The Iron and Steel Institute offers special attraction to those interested in the study of ferrous Metallurgy. An interesting feature of the policy adopted by the Iron and Steel Institute in 1916 is that it was decided to accept candidates for election as Associates. Persons not exceeding 24 years of age are therefore eligible if they possess the following qualifications: students of Metallurgy taking courses at a University college or technical school; pupils who are apprentices of metallurgists or engineers, or in metallurgical or engineering works; and persons employed in some practical or scientific capacity in metallurgical or engineering works. The subscription is exceedingly moderate—only one guinea per annum and no entrance fees—a less sum than most of even the small engineering societies charge for membership. This Associateship enables individuals interested in Metallurgy to obtain at once the whole benefits of the Institute with the exception of voting, that is, an Associate has the right to attend all meetings and receive all notices and publications.

FEDERATION OF BRITISH INDUSTRIES.—It may be interesting to add that Birmingham was practically the birthplace of the Federation of British Industries and provided its first President Mr. F. Dudley Docker, C.B., who has done so much for the city's manufacturing interests. The present President, The Right Hon. Sir Eric Geddes, G.C.B., G.B.E., is also now intimately associated with one of the large Companies in Birmingham. The Membership of the Federation consists of 1,889 Associations, manufacturing concerns, and others, of which about one-sixth belong to Birmingham. Its powerful voice is felt even in Government circles and Parliament. Despite the heavy and long continuing trade depression, recruiting of new members steadily proceeds.

The Birmingham office of the Federation covers the five counties of Warwickshire, Staffordshire, Shropshire, Worcestershire and Herefordshire. At present the local organisation is controlled by a representative and influential Area Committee under the Chairmanship of Sir David Brooks, G.B.E., who was Lord Mayor of the city during the years 1917 to 1918 and 1918 to 1919.

Authority has been obtained and when conditions are more settled, district committees will be set up in Wolverhampton and the Black Country, Coventry, Kidderminster and the Pottery district.

A LEGEND OF METALLURGY.

"The Goddess of the Pole Star, descending from the Starry firmament, became enamoured of a mortal, Sidérite, but he, loving none but his brother Sidère, repulsed her. In her wrath she transformed the devoted brothers, one into Stone and the other into Iron."

From the Poem "Ferrum" written in Latin by Father Xavier de la Saute in 1772, and translated in 1906 into French verse by the late Professor F. Osmond, Metallurgist, Paris.

This Bronze Group was prepared for the writer of this Address by the Sculptor, Mr. Frederick J. Halnon, and was exhibited at the Royal Academy, London, 1923.

Section V

Metallurgy

Siderology.—The branch of Science which we now call Metallurgy was formerly known as Siderology, and the French equivalent of this term is still used in France, where the leading Metallurgical Association is known as the Comptoir Siderurgique. In this country the word Siderology is obsolete, but " siderite " is still used as a name for magnetic iron ore, and " siderography " refers to engraving on steel.

The derivation of all these words is from Sidus a star; a group of stars; a constellation; a sky; the heavens. It seems possible, therefore, that the term Siderology was adopted in order to convey the idea that iron came from the stars in the form of meteorites of ferrous character, which are believed to have bombarded us in the early stages of the world's history. This theory has been put forward by several well-known authorities, and though it is probably only a partial explanation, it is certainly curious to find that, apart from known meteoric specimens, iron ore deposits exist on the surface of the earth or only at shallow depths.

This term " Siderology " is also mentioned because of the reference to the two shepherds, Sidère and Sidérite, in the Poem "Ferrum," first written in Latin in 1717 by Father Xavier de la Sante, and quoted in Section VII of Part II of this address. In beautiful language and imagery this poem describes the wonderful metal iron, in which the world to-day is so much interested. A translation was made into French by my friend, the late Professor F. Osmond, who did so much for the Science of Metallurgy. Plate 13 shows the Bronze Group embodying the poetical ideas so beautifully expressed by Father Xavier de la Sante. The execution of the commission for me was carried out by Mr. Frederick J. Halnon, R.B.S., and the group was exhibited at the Royal Academy this year. As a slight appreciation of the many kindnesses I have received over a long period of time from numerous French Scientists and Engineers, it has given me much pleasure to present a replica of this Bronze Group to the Conservatoire des Arts et Metiers, Paris, where my friend Dr. Léon Guillet is Professor of Metallurgy.

THE PRODUCTION OF IRON AND STEEL

Antiquity.—An Italian writer, Comm. G. E. Falck, President of the Association of Italian Metallurgical Industries, in a recent paper entitled " The Iron and Steel Industry of Italy " read before the Iron and Steel Institute, of which he is one of the Honorary Vice-Presidents, says that the Iron Industry is coeval with the first dawn of Italian

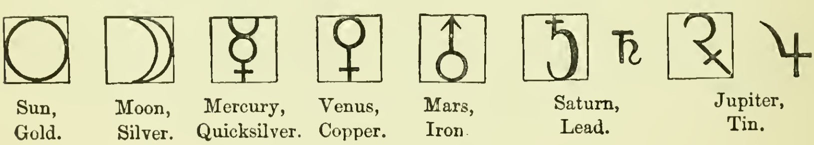
civilisation, and its origin is lost in the dim history of the "Age of Iron," in the rise of which Italy played a leading part. He points out that the iron ores of Elba have been worked since the Etruscan epoch, and the Lucomonians of Populonia built furnaces on Elba to smelt them. From the Roman Age there are indubitable proofs of a flourishing mining industry on the island. Virgil extols the generous island with its inexhaustible store of mineral wealth; Aristotle calls the iron from Elba Populonian iron, for the reason that it was smelted at Populonia; Strabo, in astonishment at the abundance of iron-bearing minerals, declared that the earth reproduced iron. It is interesting to note that Comm. Falck, like many of us, considers that one of the chief causes of the War was the fact that the Germans coveted the possession of the Briey Basin with its vast supplies of iron ore. Their geologists misled Bismarck in 1870; it was not intended to repeat the error!

Campbell says that amongst the Scythians the iron sword was a god. It was the image of Mars and sacrifices were made to it. Vulcan was a smith; Thor wielded a hammer; even Fionn had a hammer which was heard in Lochlann when struck in Eirinn.

Smiles mentions that the weapon of bronze was dull; but that of steel was bright. The "white sword of light," one touch of which broke spells, liberated enchanted Princesses and froze Giants' marrow, King Arthur's magic sword "Excalibur," was regarded as almost heroic in the romance of chivalry. This famous steel sword was afterwards sent by Richard I as a present to Tancred; the value attached to the weapon may be estimated by the fact that the Crusaders sent the English monarch, in return for it, "four great ships and fifteen galleys."

Do not let us forget, too, the work of Weland the Smith, Weland being the Scandinavian word for Vulcan, about whose name clusters so much traditional glory as an ancient worker in metals. Iron often plays an important part in mythological lore.

In the old times of alchemy the chemists of those days were not content with merely stating the names of metals, but these were also represented by curious symbols or zodiac signs as shown by the following figure, which is taken from Glauber's *Treatise of the Signature of Salts, Metals, and Plants*, published in 1658. In this the Sun represents Gold; the Moon, Silver; Mercury, Quicksilver; Venus, Copper; Mars, Iron;



Glauber said: "The extent to which the symbol touches the enclosing squares is intended to indicate the relative perfection of the metal. Now if into one of these I put the character of the Sun or Gold, viz. a round circle, it touches four parts of the square and filleth it up, signifying that among celestial and terrestrial creatures, the Sun and Gold do excel all other things in their perfection."

Saturn was supposed to influence life, sciences and buildings; Jupiter,—honour, wishes, and wealth; Mars—wars, persons, marriages, and quarrels; the Sun—hope, gain, and happiness; Venus—love and friendship; Mercury—fear, disease, debts, and commerce; the Moon—

robberies, wounds and dreams. The intrinsic quality was denoted by the planet. The Sun was regarded as favourable; Saturn, cold; Jupiter, temperate; Mars, ardent; Venus, fruitful; Mercury, inconstant; the Moon, melancholy. The days, colours, and metals also came under the same influences.

To-day we regard iron as the metal which has brought more comfort and more civilisation into the world than any other metal, useful though some of them undoubtedly are. For example, take away gold and we would hardly notice its absence from the engineering and metallurgical point of view; but take away iron and the world would rapidly sink back into barbarism.

In the *Mechanic's Encyclopædia* published in 1835, under the heading of iron, reference is made to "Meteor Steel," whatever that may have been, one of the patentees of the product being Mr. K. Martineau, a name still familiar to those in Birmingham.

In this encyclopædia it is interesting to note the reference to the output of pig iron in some of the years between 1740 and 1827.

In the year	1740	17,000	tons were made from	59	furnaces.
,,	1788	68,000	,, ,, ,,	121	,,
,,	1796	125,000	,, ,, ,,	—	,,
,,	1806	250,000	,, ,, ,,	—	,,
,,	1820	400,000	,, ,, ,,	—	,,
,,	1827	690,000	,, ,, ,,	284	,,

In the latter year the production was distributed as follows:—

Staffordshire	216,000	tons from	95	furnaces.
Shropshire	78,000	,,	31	,,
South Wales	272,000	,,	90	,,
North Wales	24,000	,,	12	,,
Yorkshire	43,000	,,	24	,,
Derbyshire	20,500	,,	14	,,
Scotland	36,500	,,	18	,,
Total ...	690,000		284	

As a contrast it may be mentioned that there are to-day at work in the United States, blast furnaces of such large dimensions that they produce about 300,000 tons annually. Thus two of these furnaces would turn out almost as much as the whole output of the 284 furnaces mentioned above. This shows the wonderful strides made by the Metallurgist during the past hundred years.

Present Day.—To give some idea of the gigantic nature of the world's iron and steel industry, there are now, in the United States alone, no less than 16,571 establishments manufacturing iron and steel, with 1,030,248 wage earners in 1921, whose total production was valued at £1,218,000,000. About one-quarter of the wage earners, one-third of the products and one twenty-fifth of the number of establishments represent the iron and steel industry proper, while the remainder comprise a great variety of metal working industries in which iron and steel are the principal basic materials. The value of the production per man was £1,180.

It may be interesting to add that the Imperial Mineral Resources Bureau states that in 1921 the total amount of iron ore mined in the world amounted to 73 million tons, of which the British Empire mined

about 6 million tons, the U.S.A. claiming $29\frac{1}{2}$ million tons. In the same year the world's production of pig iron amounted to $34\frac{1}{2}$ million tons, the share of the British Empire in this being about 4 million tons, and that of the U.S.A. $16\frac{1}{2}$ million tons. The world's production of steel ingots and castings in 1921 was 40 million tons, of which the British Empire produced $4\frac{3}{4}$ million tons, and the U.S.A. $19\frac{3}{4}$ million tons. When normal times return this total will without doubt be largely increased.

In the following Table, these figures are supplemented by the corresponding data for 1922 :—

PRODUCTION OF IRON ORE, PIG IRON, AND STEEL INGOTS AND CASTINGS IN THE YEARS 1921 AND 1922.

(Thousands of Tons)

1921	U.K.	British Empire including U.K.	U.S.	World Total
Ore Production... ...	3,478	5,753	29,380	73,000
Ore Consumption ...	5,600	8,400	33,500	73,000
Pig Iron	2,616	3,957	16,688	34,500
Steel Ingots and Castings	8,703	4,719	19,784	40,000
1922				
Ore Production ...	6,872	9,300	47,100	105,000
Ore Consumption ...	10,200	12,500	53,000	105,000
Pig Iron	4,900	6,000	26,850	50,000
Steel Ingots and Castings	5,832	6,700	33,600	59,500

The question whether the iron ore fields of the world are sufficient for the enormous consumption which is likely to occur in the future has been carefully considered by many authorities.

It appears that the present iron ore deposits of Lake Superior may be taken at 3,000 millions, those of Alsace Lorraine are 6,300 millions, and those of Brazil 7,500 millions of tons. The total iron ore reserves of the world are at present estimated to amount to 131,000 millions of tons.

Quite recently some interesting information came before me in a publication by Professor Lasereff of the Moscow University, with regard to the potentialities of Russia in respect of iron ore. Important experiments have been carried out on the basis of magnetic and other observations, also on the results of boring in the Kursk Province. These have been further examined by Professor Smirnov of the Kazan University and Professor Leyst of the Moscow University. From these observations and drillings it was found that the intensity of the magnetic disturbances was greater in the Kursk Province than in the Urals or in Sweden.

Careful estimates were prepared from the information so obtained, and it is calculated that the deposits in the Kursk region amount to the gigantic figure of 32,000 million tons of iron ore. If these estimates be correct, and they appear to be based on a scientific examination, there is still hope for that great country Russia, who so nobly sacrificed millions of her citizens in the struggle of the allies on behalf of justice and freedom. Let us hope her wounds can be healed and that she may

be persuaded to take a sane view which will enable her to regain the position to which she is entitled amongst the civilised nations of the world.

As a comparison with the output of iron it may be interesting to state that the world's output of coal, which had reached 1,476 million tons in 1913, is now slightly under that figure, that is, for the year 1922 the output was 1,332 million tons. Of this the United States raised 31% (417 million tons), Great Britain 19% (256), Germany 21% (278), including lignite, France 2.2% (32), Japan 1.8% (25), Poland 1.8% (24), and Belgium 1.5% (21).

When speaking of Metallurgical progress I should like to call attention to the fact that next year there will take place at the British Empire Exhibition one of the most important Mining and Metallurgical Conferences ever held. The untold mineral wealth of our Empire ought to be better known and exploited than is the case. It is hoped therefore that the Congress will bring about a better understanding, and help to link our Empire still more closely together with regard to these important subjects.

THE STUDY OF HIGH TEMPERATURES.—The Science of Metallurgy, notwithstanding the amount of research and investigation already accomplished, still presents in many directions a practically unexplored field for the investigator. Of no branch is this more true than that of the study of high temperatures and their effects.

Few can speak with greater authority on this subject than Dr. E. F. Northrup of Philadelphia, Pa., who in a recent paper read before the Franklin Institute expresses the belief that no path goes straighter or quicker to discoveries which will add so much to our knowledge of matter itself, and to the finding of things useful for every-day life, than the roadway of high temperature investigation.

He says that while not underrating the great value of low temperature research on the properties of matter—by such research we have penetrated deeply into a further understanding of its constitution—the upper limits of the temperature scale are now attracting more attention, for there matter pulsates with mighty energies. It takes on aspects and strange qualities that fascinate, and the hope is ever held out of discovering in the region of high temperature unsuspected properties of matter extremely useful in the every-day affairs of industry, with a view to increasing the comfort and convenience of life.

Our store of quantitative knowledge, embodied in tables of constants, of the physical and chemical properties of matter above 1500° C. is small indeed. Outside its property of giving off radiant energy, physicists and chemists have paid little attention to a quantitative examination of the properties of matter exhibited at the higher temperatures.

High temperature makes of most kinds of matter something which is entirely new ; something unrecognisable as the same stuff with which we started at ordinary temperature. What undreamed-of beneficent uses may not matter possess in this new dress, put on with *fire !*

Dr. Northrup further says that by passing to the highest temperatures there is eliminated from consideration all such phenomena as crystallisation, magnetism, surface colouring, production of aqueous solutions, the greater part of the phenomena of organic chemistry, and a multitude of other familiar physical and chemical manifestations. The science of biology outside the range of ordinary temperatures is non-existent.

Life does not seem to exist below about $-50°$ C. or above 100° C; that is, living organisms are only maintained in the form we term "life" within the narrow range of about 150° C.

When nature is studied, simplified, so to speak, we should be able to acquire a better understanding of the increasingly complex phenomena which appear as we bring the lower temperature range up and the higher temperature range down. In the light of our knowledge of nature simplified we shall be better able to interpret her more complex manifestations at ordinary temperatures.

Although Dr. Northrup's remarks are intended to refer to physical and chemical research on matter in general, they remain true if applied more specifically in connection with metals.

Indeed it is largely the requirements of the iron and steel industry which have been responsible for the improvements in apparatus and methods for high temperature measurement.

In this connection it is interesting to recall the pioneer work of Josiah Wedgwood, F.R.S., 1730-1795, who was born at Burslem, Staffordshire. He was one of the first to grasp the importance of understanding and accurately determining high temperatures. The fact that he was elected a Fellow of the Royal Society is proof that his work was appreciated.

Later developments, that is up to the present time, have sprung chiefly from the scientific work of Professor Henri Le Chatelier, F.R.S., in France, and of Professor H. L. Callendar, F.R.S., in England.

To show how limited is our experience of high temperatures reference may be made to a recent and most instructive article by Herbert Dingle in *Nature* on "The Temperature of the Stars." According to Mr. Dingle these are exceedingly high; for example, that of Vega has been stated to be 12,000° C., Pegasi 22,000° C., and Persei no less than 28,000° C. He also states that according to important authorities, it is quite probable that there are bodies in the universe at all temperatures between absolute zero and twenty million degrees Centigrade or even higher!

Metallurgists on our earth find that 1,500° C., that is, about the melting point of iron, is quite hot enough, but temperatures some twenty times or even some ten thousand times as high appear to exist in the universe. These figures can hardly be grasped by the human mind. Even the Sun's temperature of 5,300° C. pales into insignificance.

As regards mundane heat, Volcanoes in eruption show high temperatures, but apparently not more than about 1,600° C. To a Metallurgist it is hardly possible to conceive a more beautiful attempt to depict the different colours and the shades of high temperatures than that shown in the wonderful picture *Mount Vesuvius in Eruption in* 1818, painted by that renowned British artist, J. M. W. Turner, R.A. As I happen to possess this water colour picture I have had prepared specially a lantern slide of it, made for me by Messrs. Sanger-Shepherd & Co. I am going to throw this on the screen and leave you to judge for yourselves as to its high artistic merit. No mere copy, however, could ever quite come up to the beautiful tones of colour in the picture itself. These vary from dull red to white heat, that is they include temperatures from about 600° C. to 1,600° C. and are depicted in a marvellously artistic manner. Of course it may be that under high pressures in the bowels of the earth temperatures are much higher, but we have no direct evidence to this effect, and no known refractories will withstand much greater temperatures than about 1,800° C. without fusion.

The Bust in the centre of the Engraving represents King Charles II, the figure on the right Francis Bacon, and that on the left Lord Brouncker, the First President of the Royal Society.

From an Engraving by W. Holler in the Book by Thomas Sprat, D.D., F.R.S., Lord Bishop of Rochester, entitled "The History of the Royal Society of London for the Improving of Natural Knowledge," published in 1667.

Section VI

Science

Early Development in the Middle Ages.—Whilst the specialised knowledge which is required of Metallurgical students when entering upon their professional career demands close attention to the facts and figures relating to modern progress, there is also much to be learned from a study of the history of the progress of Science. I am indebted for some of the following information on this subject to the valuable *History of the Royal Society* by Weld, published in 1898.

In speaking of the early development of Science in the Middle Ages, Weld points out that we should not forget to give great credit to our countryman Roger Bacon, who was a giant of profound understanding in his generation. He was born in 1214, and his learning gained for him the title of Doctor Mirabilis from his brother Franciscan Monks. His *Opus Majus* addressed to Pope Clement the Fourth, displays a mode of philosophising far in advance of the age in which he lived. He was probably the first to see the enormous importance to mankind of the study of what we now call Science. The labours of Bacon appeared to bring forth no fruit in his time, as evidently some change disastrous to the fortunes of Science must have taken place about 1230, soon after the foundation of the Dominican and Franciscan orders. The members of these orders fell back upon the adoption of the Aristotelian Philosophy, which unfortunately resulted in deferring for three centuries the reforms in study which Roger Bacon had urged as matters of crying necessity in his own time.

It is satisfactory to note that this country held a conspicuous position in the philosophy of the Middle Ages, in fact Professor de Morgan gives a list of no fewer than 96 English Mathematical and Astronomical writers between 1068 and 1599, so that it was rightly said by Captain Smythe in his *Celestial Cycle* that "England has contributed her full quota to the series of philosophical and zealous inquirers who have so largely opened the human intellect."

Incidentally it may be mentioned that the first society instituted for the investigation of Physical Science was that established at Naples in the year 1560 with the name of Accademia Secretorum Naturæ, but their studies were prematurely brought to a close, the Academy having been dissolved by the Ecclesiastical authorities.

The important Accademia del Cimento published reports of experiments made by its members in 1666. Amongst these Castellio and Torricelli, disciples of Galileo, were the most illustrious; to them are due many of the discoveries in the Science of Hydraulics; whilst the invention of the Barometer alone renders the name of Torricelli

immortal. He made this discovery in 1643 ; and in 1648 Pascal, by his celebrated experiment on the Puy de Dome, established the theory of atmospheric pressure beyond dispute.

It was about this time, 1636, when a very curious and scarce tract entitled *The Constitutions on the Museaum Minervæ* was published, relative to the attempt made to establish a Scientific Institution under the Patronage of Charles I, who in the eleventh year of his reign granted a Special Licence under the Privy Seal, dated at Canbury June 26th, 1635, to establish a College or Academy under the title of Minerva's Museum, for the instruction of the young nobility in the liberal arts and sciences. The aristocratic tendency of the Institution may be judged by its first rule, namely: "Every man that shall be admitted into the said Museaum shall bring a testimoniall of his arms and gentry, and his coate armour tricked on a table, to be conserved in the Museaum." The College was to be erected in Covent Garden; the Professors selected and their duties were as follows:

Edward May Doctour of Philosophie and Physick shall reade and professe these: Physiologie, Anatomie, or any other parts of Physick.

Nicholas Phiske the Professour of Astronomie shall teach these: Astronomie, Opticks, Navigation, Cosmographie.

John Spidell the Professour of Geometrie shall teach these: Arithmetique, Analyticall Algebra, Geometrie, Fortification, Architecture.

Thomas Hunt the Professour of Musick shall teach these: Skill in Singing, and musick to play upon Organ, Lute, Violl, and other instruments.

Walter Salter the Professour of Languages shall teach these: Hebrew, Greek, Latine, Italian, French, Spanish, High Dutch.

Michael Mason the Professour of Defence shall teach these: Skill at all weapons and wrestling, also Riding, Dancing and Behaviour.

As Dr. Weld states in his account of this Academy: "The time was too unsettled to allow so fair a project to ripen, and it is almost needless to state, that Minerva's Museum never attained its contemplated greatness."

France was also moved to follow the stirring example of Italy, and the French Academy was established, springing from a private society of men of letters at Paris in the year 1629. This institution was subsequently incorporated with the Academy of Sciences and that of Inscriptions and Belles Lettres. Although France thus early founded a society for the cultivation of literature, yet to England belongs the high honour of being the first country, after Italy, to establish a society for the investigation of Physical Science. The period had arrived when experimental philosophy, to which Francis Bacon had held the torch, and which had already made considerable progress, specially in Italy, was finally established on the ruins of arbitrary figments and partial inductions.

It was fortunate that during this period we were able to claim as our countrymen those two great pioneers Dr. Gilbert and Sir Francis Bacon.

Dr. Gilbert (1540-1603).—Dr. Gilbert of Colchester, Physician to Queen Elizabeth, made discoveries in Magnetism and Electricity which caused him to be known as the Father of Magnetism. He is even credited by some to have been the first to show that Metaphysics must give place to Science, and Aristotelian ideas cease to dominate thought.

To quote Dr. E. F. Northrup, " Then Metaphysics gave place to Science, and Aristotle ceased to dominate thought, because there came as it were a gift from Heaven in the form of a desire on the part of men to learn about Nature through controlled observation. Whilst Francis Bacon formulated in a speculative way the new scientific method, it was Gilbert, the Father of Magnetism, who first put into effect, and reported in 1606 his success in his classic *De Magnete*. The Science of Nature as observed in our dwelling place, the earth, made an advance comparable to the butterfly emerging from its chrysalis."

Sir Francis Bacon (1551-1626).—To Sir Francis Bacon, afterwards Lord Verulam, Viscount St. Albans, Lord Chancellor of England, we owe that announcement of the new scientific method which did so much to sweep away the earlier systems and admit the light of scientific truth.

His various works, and particularly that on the Instauration of the Science, have caused him to be regarded as the creator of the school of experimental philosophy. He was in some measure responsible for the founding of the Royal Society ; for it was whilst the memory of Bacon was recent, and the spirit of his philosophy newly spread, that the establishment of this great scientific society was accomplished.

After falling from his high political estate, he devoted his remaining years to scientific pursuits. His life, alas, fell a sacrifice to some philosophical experiments. A retort which he had been using burst, some fragments struck his face, and the wounds induced fever, of which he died.

It is also interesting to give from Green's *History of the English People* a short résumé of his well-considered remarks on the revival of English letters and, what is more important to us this evening, the commencement of English scientific studies.

In speaking of this epoch, the late Professor Green said that " the general awakening of national life, the increase of wealth, of refinement and leisure, which marked the period, had been accompanied by a quickening of English intelligence, which found vent in an upgrowth of grammar schools, in the new impulse given to classical learning at the Universities, in a passion for translations which familiarised all England with the masterpieces of Italy and Greece, and above all in the crude but vigorous efforts of Sackville and Lyly after a nobler poetry and prose.

" The sphere of human interest was widened as it has never been widened before or since by the revelation of a new heaven and a new earth. It was only in the later years of the sixteenth century that the discoveries of Copernicus were brought home to the general intelligence of the world by Kepler and Galileo, or that the daring of the buccaneers broke through the veil which the greed of Spain had drawn across the New World of Columbus.

" We see therefore the influence of this new and wider knowledge of the world, not only in the life and richness which it gave to the imagination of the time, but in the immense interest which from this moment attached itself to man. Shakespeare's conception of Caliban, like the questionings of Montaigne, marks the beginning of a new and a truer, because a more inductive, philosophy of human nature and human history. The fascination exercised by the study of human character showed itself in the essays of Francis Bacon, and yet more in the wonderful popularity of the drama. And to these larger and world-wide sources of poetic powers was added in England the impulse

which sprang from national triumph, from the victory over the Armada, the deliverance from Spain, the rolling away of the Catholic terror which had hung like a cloud over the hopes of the people. With its new sense of security, of national energy and national power, the whole aspect of England suddenly changed. As yet the interest of Elizabeth's reign had been political and material; the stage had been crowded with statesmen and warriors, with Cecils and Walsinghams and Drakes. Literature had hardly found a place in the glories of the time. But from the moment when the Armada drifted back broken to Ferrol, the figures of warriors and statesmen were dwarfed by the grander figures of poets and philosophers. The triumph at Cadiz, the conquest of Ireland, pass unheeded as we watch Hooker building up his *Ecclesiastical Polity* among the sheepfolds, or the genius of Shakespeare rising year by year into supremer grandeur in a rude theatre beside the Thames.

"It was this lofty conception of the position and destiny of natural science which Bacon was the first to impress upon mankind at large. The age was one in which knowledge was passing to fields of inquiry which had till then been unknown, in which Kepler and Galileo were creating modern astronomy, in which Descartes was revealing the laws of motion, and Harvey the circulation of the blood. But to the mass of men this great change was all but imperceptible; and it was the energy, the profound conviction, the eloquence of Bacon which first called the attention of mankind as a whole to the power and importance of physical research. It was he who by his lofty faith in the results and victories of the new philosophy nerved his followers to a zeal and confidence equal to his own. It was he who above all gave dignity to the slow and patient processes of investigation, of experiment, of comparison, to the sacrificing of hypothesis to fact, to the single aim after truth, which was to be the law of modern science."

This noble and beautiful language of Green is most apposite and so well expressed that I make no excuse for quoting fully from him.

DEVELOPMENTS IN THE SEVENTEENTH CENTURY

Macaulay in his famous History of England rightly pointed out that the seventeenth century was a period of surprises, and most momentous in every way in its bearing upon the developments of human thought in Politics, Sociology, and Science. The Dean of your Faculty of Science, Professor F. W. Burstall, has also ably developed this in his excellent Address regarding the History of Mechanical Engineering, read before the Women's Engineering Conference held in London early this year. I refer more fully to his views in Section IX, devoted to the consideration of "The Development of Engineering."

The first real development in the study of Science appears to have occurred in our country during the Seventeenth Century which included the formation of the Royal Society in 1660 with its expressive motto "Nullius in Verba," its full formal constitution and foundation taking place on July 15th, 1662. Portraits and signatures of the Founder, also some of the most notable Fellows, of the Royal Society, are shown in Plates 15 and 16.

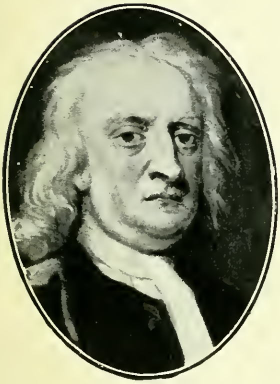
In Plate 14 I show an engraving by Hollar in 1667. The bust in the centre represents King Charles II, the figure on the right Sir Francis

THE FOUNDER, AND SOME OF THE PAST NOTABLE FELLOWS OF THE ROYAL SOCIETY.

(Most of these are given by kind permission of the Council of the Royal Society.)

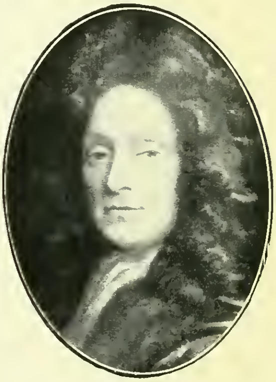
SIR HUMPHRY DAVY
1778-1829

MICHAEL FARADAY
1791-1867

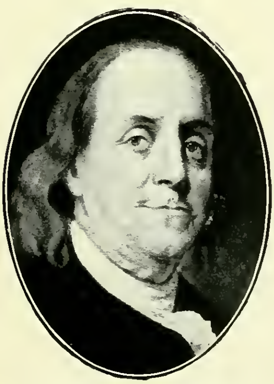


SIR ISAAC NEWTON
1642-1727

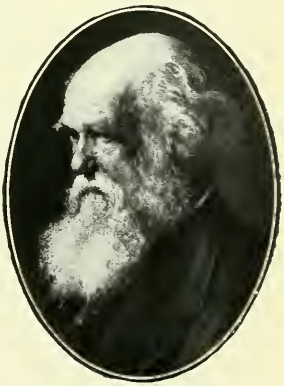
CHARLES II.
The Founder
1630-1685



SIR CHRISTOPHER WREN
1630-1723



BENJAMIN FRANKLIN
1706-1790



CHARLES DARWIN
1809-1883

Bacon, the originator of the Royal Society, and that on the left Lord Brouncker, its first President.

It will be noticed that various instruments and apparatus are shown in the engraving. I referred the question of their meaning to the expert opinion of my friend Dr. Charles Singer, F.R.S., the distinguished authority on the history of Science. Dr. Singer has been able to identify on the left of the engraving an instrument for taking the angular distance between two objects and another which was used for measuring the altitude of the stars. A clock and gnomon are also easily distinguishable, whilst a telescope is visible in the background. On the right of the engraving is a thermometer of the type invented about 1600 by Sancto Sanctorio, and a compass, below which is an instrument that can be no other than a theodolite. Two adjustable pendula are also shown. There are also four or five other instruments the exact nature and use of which are uncertain.

Let us now briefly recapitulate some of the outstanding features of that time:

James I came to the throne in 1603, the union of the English and Scottish Parliaments taking place later on, in 1707. In 1604 he was termed " King of Great Britain." The Gunpowder Plot followed in 1605. Shakespeare, the greatest Englishman of letters, died in 1616.

Charles I succeeded his father in 1625 ; then followed the Civil War, and finally his death occurred in 1649. In 1651 Cromwell's great victory took place in Worcester, not so far from Birmingham. The Monarchy was re-established under Charles II in 1660.

As just shown, Bacon inspired the foundation of probably the most important body of Scientific men in the world, namely the Royal Society, in 1662. The Great Plague occurred in 1665, followed in the next year by the Great Fire of London. Milton, whose beautiful stanza on education forms the foreword of this Address, died in 1674. The Habeas Corpus Act was passed in 1679. The National Debt began in 1692, and has now reached the colossal figure of Eight thousand Million Pounds, and still we live on ! The Bank of England was incorporated in 1694.

The foregoing historical facts are mentioned because in these times commenced the first great advance in Science, and not long afterwards, in the next century, followed the remarkable invention and development of steam power by James Watt.

The words of Macaulay are so striking with regard to this wonderful century, 1600 to 1700, that I venture to quote them somewhat fully from his *History of England*. It is satisfactory to note that he awards our country its full and deserved position.

Macaulay said that English genius was then effecting in Science a revolution which would, to the end of time, be reckoned amongst the highest achievements of the human intellect. Bacon had sown the good seed in the sluggish soil and in an uncongenial season.

In the year 1660 the new field of Science obtained ascendancy. In that year the Royal Society, destined to be a chief agent in the long series of glorious and salutary reforms, began to exist. In a few months experimental science became all the mode. The transfusion of blood, the ponderation of air, the fixation of mercury, succeeded to that place in the public mind which had been lately occupied by the controversies

of the Rota. Dreams of perfect forms of government made way for dreams of wings with which men were to fly from the Tower to the Abbey, and of double-keeled ships which were never to founder in the fiercest storms. All classes were hurried along by the prevailing sentiment. Cavalier and Roundhead, Churchman and Puritan, were for once allied. Divines, Jurists, Statesmen, Nobles, Princes swelled in triumph of the Baconian philosophy.

Poets sang with emulous fervour the approach of the Golden Age. Dryden, with more soul than knowledge, joined his views to the general acclamation, and foretold things which neither he nor anybody else understood. In his great poem *Annus Mirabilis* he predicted that the Royal Society would soon lead us to the extreme verge of the globe, and there delight us with a better view of the moon! In fact, human imagination ran riot.

On November 20th, 1663, the Royal Society, according to MS. preserved in the British Museum, consisted of 131 Fellows, of whom 18 were Noblemen, 22 Barons and Knights, 47 Esquires, 32 Doctors, 2 Bachelors of Divinity, 2 Masters of Art and 8 strangers or foreign Members.

It will thus be seen that Great Britain was at the period mentioned well launched in the new philosophy now termed by us "Science," and our country has every reason to be proud of the share it has taken in the world's development. Let us all bear this in mind and each in turn do his utmost to maintain the high prestige of our Empire, not only on the field of battle and on the high seas, but also in the realms of scientific thought. I am confident that we need never fear comparison with other nations, and believe that we shall continue to maintain our proud position if we do but remember these great traditions of the past and consistently try to do our share in preserving them. The beautiful words of our Blind Poet, that great Englishman, Milton, should ever ring in our ears, when in his *Tractate of Education* he said:

"I call a complete and generous education that which fits a man to perform justly, skilfully, and magnanimously all the offices, both private and public, of Peace and War. . . . I shall detain you no longer in the demonstration of what we should not do, but straight conduct you to a hillside, where I will point you out the right path of a virtuous and noble education; laborious indeed at the first ascent but else so smooth, so green, so full of goodly prospect and melodious sounds on every side that the harp of Orpheus was not more charming. . . . Be enflamed with the study of learning, the admiration of virtue, and stirred up with high hopes of living to be brave men and worthy patriots, dear to God, and famous to all ages."

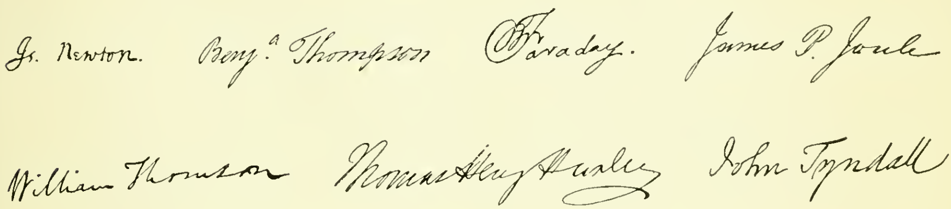
DEVELOPMENT IN THE NINETEENTH CENTURY

The long early period of research work in Science may now appear to us as of little importance in its intrinsic results, also as having been slow and painful in its progress. But this was not so, the evolution was merely proceeding. The movement culminated in the first half of the nineteenth century, when Scientific Engineering and Metallurgy began to appear. Speaking of the lines of work dealt with by the writer in this

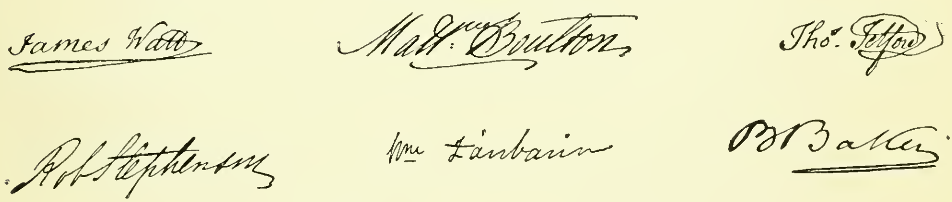
SIGNATURES OF SOME OF THE PAST NOTABLE FELLOWS OF THE ROYAL SOCIETY, COLLECTED FROM DIFFERENT PAGES OF THE CHARTER BOOK.

(By kind permission of the President and Council of the Royal Society.)

PHYSICISTS



ENGINEERS



The signatures are half full size.

CHARLES II.
Founder and First Fellow of the Royal Society, 1664.

JAMES (DUKE OF YORK)
Second Fellow 1664, and afterwards James II.

LORD BROUNCKER
The First President of the Royal Society 1663.

PHYSICISTS

ISAAC NEWTON
Discoverer of the Law of Gravitation 1671

BENJAMIN THOMPSON
Afterwards Count Rumford. Founder of The Royal Institution, and the Rumford Medal 1779.

MICHAEL FARADAY
Discoverer of the Laws of Electrical Induction 1824.

JAMES P. JOULE
First to accurately measure the Mechanical Equivalent of Heat 1850.

WILLIAM THOMSON
Afterwards Lord Kelvin. Very eminent Physicist and Mathematician 1851.

THOMAS HENRY HUXLEY
Biologist, Philosopher and Man of Letters 1851

JOHN TYNDALL
Distinguished Experimentalist and brilliant writer 1852

ENGINEERS

JAMES WATT
Inventor of the Steam Engine 1785

MATTHEW BOULTON
Eminent Engineer and Co-partner with Watt 1785.

THOMAS TELFORD
The First President of the Institution of Civil Engineers in 1820. Effected great advances in road construction 1827.

ROBERT STEPHENSON
Distinguished Engineer 1849

WILLIAM FAIRBAIRN
Designer of the Menai Straits Bridge 1850

BENJAMIN BAKER
Designer of the Forth Bridge 1890

The date affixed to each name represents the year in which the Charter of Fellowship was signed.

Address, we now begin to find pamphlets and books relating to the Engineering and Metallurgical Arts. Until, however, Faraday carried out his wonderful researches on electricity but little was known of this branch of Science. It was he who first opened up this avenue which has led to the practical application of the new form of energy, Electricity, which, one might justly say, is being developed and controlled by man to the great benefit of the world generally.

As a small example of this great advance in thought in the early part of the nineteenth century, there is shown in the Frontispiece of this Address an interesting illustration entitled "The Temple of Science," which appeared in *The Engineers' and Mechanics' Encyclopædia* published 1835. This illustration claimed to comprehend "Practical Illustrations of the Machinery and Process employed in every description of manufacture of the British Empire." The author of the book was Luke Herbert, Civil Engineer, Editor of the *History and Progress of the Steam Engine*, *Register of Arts*, and *Journal of Patents and Inventions*.

I am indebted to my friend Mr. H. W. Dickinson, Secretary of the Advisory Council of the Science Museum, South Kensington, for the loan of the book from which this illustration has been taken.

In this frontispiece is shown in the distance the first locomotive drawing railway carriages filled with coal or with the gentry of the day wearing "top hats," it is not certain which of them! In the air is an airship or dirigible balloon; in the background a demonstration of the Torricellian vacuum; and an apparatus for the demonstration of Static Electricity. In the foreground can be seen allegorical figures examining plans of mechanical inventions, including a water tube boiler and an engine with governor. The foreground is strewn with various tools and apparatus relating to Engineering, Metallurgy and Chemistry. Probably the city on the hill in the picture is Birmingham, at any rate let us think so!

I may remind my readers that the first locomotive made by George Stephenson in 1814 travelled at the rate of about 6 miles per hour, whilst the *Rocket*, in 1829, possessed what was then considered to be the high speed of 25 to 35 miles per hour.

Whilst much of this may now seem childish to us, let us not forget that the ideas there depicted are those upon which we have built and founded our present advances, almost bewildering by their number and startling nature.

Present Day.—In the mechanical, metallurgical and electrical arts we have to-day our railway trains running at speeds averaging over 50 miles and often reaching 80 miles per hour; also trains drawing, in America, loads of 15,400 gross tons in one train comprising 111 cars, with a total length of 6,100 feet, or $1\frac{1}{6}$ miles, and for the greater part of the journey with one locomotive. This tonnage is about as much as that carried by a steamer of 17,050 tons displacement and 460 feet in length. We have steamships of some 60,000 tons, over nine hundred feet in length, far excelling the *Great Eastern*, built only sixty-six years ago, which was in its day considered a prodigy; motor-cars which will carry us comfortably at high rates of speed on our excellent roads—a system of travelling which has further helped to revolutionise modern life; aeroplanes flying at the rate of even four miles per minute for those who like such speedy travelling; telephones making possible conversation over a distance of 3,000 miles; wireless with a range so much wider as to be almost incredible; broadcasting, and a thousand and

one other advances too numerous to mention, to say nothing of the immense advances brought about in the field of Physics and Chemistry.

There are wonderful facilities to-day for study and research in every branch of Science, and, considering the fields of Metallurgy and Chemistry alone, what would not early workers such as Dr. Priestley—and even Dr. Percy, a century later—have given to possess the opportunities offered to students in the well organised and well equipped laboratories of to-day ?

If the modern advantages presented to us by Science were taken away, Metallurgy, whether ferrous or non-ferrous, would rapidly decline and eventually disappear. The old days of mysterious alchemy and rule of thumb have gone for ever, and Science blazes its trail through the unknown, conquering little by little, and adding ever in increasing ratio to our stock of knowledge. If this progress is used for the general benefit of mankind, then the world must surely be a better place in which to live. The discoveries of Science are shared by all, from the lowest to the highest.

One of our foremost Political Leaders, himself a Scientist, the late Lord Salisbury, has well said : " We live in a small bright oasis of knowledge surrounded on all sides by a vast unexplored region of impenetrable mystery, and from age to age the strenuous labour of successive generations wins a small strip from the desert and pushes forward the boundary of knowledge."

It seems to me that it is now for the Political Economist to bring his section of knowledge into more active evidence and operation.

The Importance of Scientific Study.—A valuable conference was held in London on May 3rd, 1916, on the subject of " The Neglect of Science." The late Lord Rayleigh presided, ably assisted by Sir E. Ray Lankester, F.R.S. An excellent discussion took place, and in my own contribution I pointed out the remarkable fact that during the last hundred years there had only been one scientific man holding an official position in the Government of the day.

This seems extraordinary, and to some extent explains the strong official and bureaucratic position taken up by those managing the affairs of State. It also explains why Science has not had—and even now is not obtaining—its fair show. To use the words of my friend the late Sir William Osler, F.R.S., Science has been a Cinderella left in the kitchen.

The importance of Science to the nation, its proper and organised study, demands a Minister of Science. I believe that extraordinary advantages would spring from such a measure. If we let the opportunity slip, it is to be feared that we shall wake up some day to find that our enterprising cousins over the water have adopted the principle before us. Our pure Scientists still hold their own in the world, nor can it be said that our workmen or artisans are at fault. It is the still greater application of Science to Industry which we must foster and encourage.

We must not rest satisfied with matters as they are, and in this connection some words may be quoted from one of our most eminent Chemists, Sir William J. Pope, F.R.S., who did so much for the country during the War. He strongly recommends consideration of the formation of an Advisory Science Committee in connection with the Government or the Board of Trade. It is well known that the Advisory Committee

of the Department of Scientific and Industrial Research does not meet this want, because it has no power nor can it introduce points with regard to the importance of Science to every man, woman and child in the kingdom.

Again quoting Sir William Osler's wise words, Science is still the Cinderella left in the kitchen. There is far too much neglect of her claims. When some special situation arises, for example, the inconveniences and necessities produced by a great war, then she is the shining princess, but all this fades away and our public is apt to lapse into dull quiescence, still leaving the bureaucracy top dog, and Science is again relegated to a secondary position.

In the Civil Service examinations every possible encouragement is given to Classics, but training in Science is left quite in the background. The marks obtainable for Science are only about 10% of the whole. In an important Government establishment in this country devoted to educational work, about 90% of the principal officials are of Classical education and about 5% of Scientific training. It is therefore small wonder that the teaching of Science has been considered as of almost secondary importance.

It is also regrettable to think, as recently stated by a well-known educational expert, that there are in this country about three million young people, 80% of whom, between the ages of fourteen and eighteen, attend neither day nor evening school. In some cases their education comes to a dead stop at the age of twelve.

One of the leading Scientists of the day, Sir J. J. Thomson, Past-President of the Royal Society, has made the following important statement: "I recognise—and I know no man of Science who does not—the necessity of literary studies as a part of the education of every boy and girl, but I must protest against the idea that literature has a monopoly in the mental development of the individual. The study of Science widens the horizon of his intellectual activities, and helps him to appreciate the beauty and mystery which surround him. It opens up avenues of constant appeal to his intellect, to his imagination, to his spirit of inquiry, to his love for truth. So far from being entirely utilitarian, it often lends romance and interest to things which, to those ignorant of Science, make no appeal to the intellect or imagination, but are regarded by them from an exclusively utilitarian point of view. A knowledge of Science brightens and widens the intellectual life, and is a constant stimulus to the intellect and imagination.

"The question of the position of Science in schools is of vital importance; I think we ought also to pay attention to the need for sustaining and stimulating in after-life the interest in Science which we hope will have been aroused at school. We should encourage and develop efforts to bring to the notice of the public those results of Science which are of general interest. I am not sure that we do all that is possible in this direction, and yet it seems our duty to the community to give it everything which can add interest to life and stimulate the intelligence; to do everything in our power to increase appreciation and interest in Science among our citizens; without such appreciation a full utilisation of the resources of Science and adequate encouragement for its development is impossible in a democratic country."

It was pointed out a short time ago in an excellent article in *Nature* on "Current Topics and Events" that there is at present a serious

hiatus in our organisation and co-ordination of education. This is shown in a most remarkable manner by the following facts.

It was recently announced in the Press that Professor A. G. Green, Director of Research of the British Dyestuff Corporation, had resigned his post on account of dissatisfaction at the lack of technical knowledge of the Board of Directors, and his belief that the permanent establishment of the dyestuff industry in this country is impossible under these conditions. It was pointed out that in our country it is unfortunately quite common for power to be in the hands of people without the scientific knowledge essential to make the best use of it for industrial and social progress. Professor Green has proved by experience what has often been pointed out in *Nature* and also publicly stated by scientific workers in various industrial fields.

In political appointments the same principle is adopted of placing the power over scientific departments in the hands of politicians without regard to their scientific knowledge or training. A recent instance showed that four different Government posts had been occupied by the same Minister in less than one year. In the particular case in question we all recognise the value of the Minister's work, but surely it is not possible for him to possess the necessary knowledge for all these various departments of public welfare. As *Nature* says, "Though it is accepted that a Chancellor of the Exchequer should know something about Finance and a Solicitor-General something about Law, apparently a Minister of Health need not know anything about Science in order to control the manifold activities of a department mainly concerned with scientific problems." In calling attention to this instance, there is not the slightest intention of criticising the individual in question, who has done and is doing splendid work for his country. It is, however, the system which appears to be wrong.

Could there be a more striking instance of the great necessity for this country to seriously consider the appointment of a Minister of Science for its encouragement and support in the best interests of the country? One can hardly imagine that anyone would be appointed to such an office unless fully qualified in the necessary scientific attainments. The advice and help of such a man would surely prove invaluable to the Cabinet and therefore to the nation.

A further instance is that mentioned by Tyndall in his book *Faraday as a Discoverer*, where he gives interesting proof of the utter lack, in most cases, of the appreciation of the scientific mind by our political chiefs.

It appears that in the year 1835 Sir Robert Peel wished to offer Faraday a pension, but that great Statesman quitted office before he was able to do this. When Lord Melbourne came into office he desired to see Faraday, and during the interview evidently used language that was in some way derogatory to Science and its aims. The result was that Faraday quitted the Minister with his own resolves and that evening he left his card with a short decisive note at the residence of Lord Melbourne stating that he had manifestly mistaken his Lordship's intention of honouring Science in his person and declining to have anything to do with the proposed pension.

A friend of Faraday and the Minister tried to arrange matters between them, but Faraday would not be moved. After many fruitless efforts his friend at length begged Faraday to state what he would require of

Lord Melbourne to induce him to change his mind. He replied: "I should require from his Lordship what I have no right or reason to expect he would grant—a written apology for the words he permitted himself to use to me." Fortunately the required apology came frank and full, creditable alike to the Prime Minister and the Philosopher. But why should Faraday, one of the greatest of all English Scientists, have been subjected to this treatment, which no doubt arose by reason of the lack of knowledge on scientific subjects of the chiefs of the department concerned.

SCIENCE DAY.—Quite recently it has been proposed in France to have a Science Day which should bring home to all classes the great importance of this branch of human knowledge. Asked with regard to the suggestion my friend, Professor Henri le Chatelier, said, and rightly so, that what was chiefly required to advance Science was serious workers having the sacred fire in their hearts.

I have also sounded several of my scientific friends on the subject. One thought the idea would be a good one if no money was wanted; another, connected with our great Science Museum in London, liked the idea and would be glad to have the Science Museum brought in prominence. I am referring elsewhere in my Address to this subject. The Editor of one of our chief papers devoted to Science approved of the idea but would like to know more about what was proposed to be done.

My suggestion is that a Science Day might be arranged in which the Universities of the nation, including of course Oxford and Cambridge, should be asked to co-operate; also the various Applied Science Departments; Colleges; Schools, public and private; Museums; Public Libraries; Scientific and Technical Institutions; and other bodies.

In such an attempt I would like to enlist the sympathies of the Labour Party, as their journals, even of the most extreme kind, would surely lend a helping hand. In fact one of the main objects of celebrating such a Day would be to interest Labour and its representatives.

With the celebrations might be included references to eminent British Scientists of the past, showing what a large part they have played in the world's progress. Perhaps this suggestion sounds impracticable, but I feel that some day a celebration of this nature will materialise.

SCIENCE AND INVENTION.—It was recently stated by the *Sunday Times*, in a contribution by a Scientific Correspondent, that the League of Nations Commission for International Intellectual Co-operation has formulated a plan under which scientists will be enabled to protect their rights in scientific discoveries in the same way as musicians and authors. The scheme has gone so far as to be submitted to the Council and Assembly of the League, and legislation of an international character will be recommended to give effect to this proposition.

There is no doubt that with few exceptions Scientists trouble themselves little, if at all, with the industrial application of the results of their researches. Only too often, the natural forces and phenomena discovered by the Scientist have been exploited by men who have contributed nothing to the discovery or to the discoverer.

This has been particularly the case in the fields of Chemistry and Electricity. In the minds of some, the application of chemical science to industry in the last fifty or sixty years has been thought to be due

to German men of Science. This is altogether wrong ; the basic discoveries in that Science have been largely made by investigators in other countries, who used them only as stepping-stones to further work in pure Science. Germany, however, never failed to make use of the commercial application of such discoveries, and, though in one sense we cannot blame them, at any rate the Germans had no right to try and make the world believe they were the real and original discoverers. By systematic exploitation and development since 1870 Germany has built up large industries and laid the foundations of their important foreign trade. But nearly all this was gained on an entirely undeserved reputation for original research work in the domain of Chemistry.

Similarly in Electrical Science, the above-mentioned Scientific Correspondent considers that, with the exception of Ohm, there is scarcely a name connected with this Science which Germany can claim.

Science and Religion.—There is still deep down in the minds of many the feeling that Science is inimical and antagonistic to Religion. The best answer to this is the fact that Religion—and in this term I make no reference to any particular creed—has now a firmer and more substantial hold than ever upon the minds of civilised human beings.

In this respect I would like to quote from one of the recent and excellent Research Narratives issued by the Engineering Foundation on this subject. The following words are taken from their Research Narrative No. 63, issued in August, and based upon a statement formulated by Dr. Robert A. Millikan, Director of Norman Bridge Laboratory of Physics, California Institute of Technology, and signed by thirty-five leaders in Religion, Science, and affairs. These men live in many parts of the United States and have diverse religious, scientific and business interests. The full statement and the names were printed in *Science*, June 1st, 1923 : " The purpose of Science is to develop, without prejudice or preconception of any kind, a knowledge of the facts, the laws and the processes of nature. The even more important task of religion, on the other hand, is to develop the consciences, the ideals and the aspirations of mankind. Each of these two activities represents a deep and vital function of the soul of man, and both are necessary for the life, the progress and the happiness of the human race."

I have tried to trace, even if imperfectly, the History of Science and its progress. The meaning of the word Science, from Scientia—knowledge, and from Scire—to know, shows its object, that is to ascertain the Truth, and as Milton has rightly said, " Who ever knew Truth put to the worst in a free and open encounter."

In stimulating the further interest in Science of the younger men amongst us I trust that this will at the same time stimulate their interest in Truth which is mighty and must prevail.

Section VII

The Science Museum

May I say a few words about the Science Museum at South Kensington which is of national importance and is not as much known as it should be. As a member of the Advisory Council, and knowing something of the valuable work done by the Museum, I would suggest that everyone interested in invention and research—and who is not nowadays—should pay a visit to this Museum which is open every day from 10 a.m. to 5 p.m. It is now under the able Directorship of Colonel H. G. Lyons, F.R.S., aided by an Advisory Council comprising, amongst others, the following members: Sir Hugh Bell, Bt. (Chairman), Sir Richard Glazebrook, Sir Thomas Holland, and the Hon. Sir Charles Parsons.

The Museum was commenced in 1857, and has been growing steadily since then. Its origin was due to the action of the Society of Arts, who presented to the Government a number of models of machinery, examples of structures and building materials, educational apparatus, and other subjects. It was further extended, largely as a result of the Fourth Report in 1874 of the Royal Commission on Scientific Instruction and the Advancement of Science. The Secretary of the Commission was the late Sir Norman Lockyer, F.R.S., to whose labours was due the bringing together, in 1876, of a considerable portion of the collection of Scientific Instruments and Apparatus in the Museum.

In 1883 a further addition was made by the presentation of a large number of most interesting objects collected in the Patent Office Museum by Mr. Bennet Woodcroft, these being handed to the Department of Science and Art for the Science Museum. Naval and Marine Engineering collections have been lent and given from time to time by the Admiralty, also by shipbuilding and engineering firms.

The new Eastern Block was due to representations made to the Board of Education in 1909 by a Deputation and a Memorial from those prominently interested in the advancement ef pure and applied Science. Sir Henry Roscoe, who did so much for the Science of Chemistry in this country, presented the Memorial and gave great assistance.

Unfortunately, little was done before the War came, when all work was stopped, and although it is now being pushed on again, the area being prepared for new exhibits is far too small. This must be increased otherwise the Museum cannot keep pace with the rapid developments in Engineering, Electricity, Metallurgy, Aeronautics, and other branches.

It is hoped that centres outside London will do all they can to assist the Science Museum Committee by urging upon the Government itself the great importance of providing adequate accommodation and pushing on the new buildings as rapidly as possible.

As pointed out in *Nature* of June 30th, 1923, by exhibited objects the Museum affords telling illustration and exposition pertaining to the various branches of Science within its field and of their applications in the arts and industries. It also preserves appliances which hold honoured places in the progress of Science or in the history of invention, and with such exhibits it associates the names of the great men to whom the world owes these successive advances. This human element in the interests which the Science Collections present accounts for no small part of the crowds who visit the galleries at times when any large section of the public is free from work. The exhibited machines and models, many of them in motion, or other inventions which have created or revolutionised industries and have altered the conditions of life, arouse in even the most casual of visitors something more than admiration for the genius and skill of the inventor. Such objects as those illustrating early steam engines, telegraphs and telephones, or the successive stages of the development of ships, never fail to appeal to popular intelligence and imagination. Indeed, many of the treasures of the Science Museum are irreplaceable in respect of value for the intellectual inspiration of the people.

One point with regard to the Exhibits in the Museum is sometimes not realised, namely, that the Museum is not only a development of different groups of Science and Technology there illustrated, but is also a permanent exhibition of current practice in each of them, unfortunately not so completely as should be the case, simply for want of space.

Owing to the many and rapid advances being made in Science, as also in technical practice, a Departmental Committee prepared, in 1912, a scheme for enlarging the Science Museum, or National Museum of Science and Industry, and their Report (Report of the Departmental Committee on the Science Museum and the Geological Museum, 1911, Cd. 5625 ; Part II. 1912, Cd. 6221) was accepted by the Board of Education.

The Committee required 265,000 square feet, of which 33,000 occupied by the present Museum have been made use of for the Imperial War Museum exhibits recently removed from the Crystal Palace, which whilst of interest hardly represent developments in the Arts of Peace. Owing to this and other causes, only 90,000 square feet are available instead of 265,000. The work on the extensions was commenced before the War, but had necessarily to be stopped, in fact the buildings as far as they had gone were used for War purposes.

Funds were partly found by the Government and partly by a donation of £100,000 from the Royal Commission for the Exhibition of 1851.

A few months ago a meeting was attended by representatives from thirty Scientific and Technical Societies, when a resolution was passed unanimously urging upon His Majesty's Government the importance of completing the whole of the Eastern Block at once, thus raising the space available for exhibition to 180,000 square feet.

It is obvious therefore, that there should also be put in hand preparations for a Central Block, as recommended by the Committee. Unless this is done, the Science Museum will remain, relative to the World of Science generally, in the somewhat Cinderella-like position which it has had to occupy for the last fifty years.

In spite of its disadvantages, defective access, and no frontage to a main thoroughfare, visitors attend the Museum at the rate of some half million per annum, in fact last Easter Bank Holiday the attendance

was 9,000 more than that of any other Museum in London. During the first six months of this year there was an increase of about 8,000 visitors over the number for last year.

Total Attendance

1911	1912	1913	*	1920	1921	1922	1923 to July
398,000	417,000	345,000	*	477,000	446,000	494,000	193,000

* The Museum was partially closed during the War and used for official purposes.

To give an idea of the importance of the Museum let me say that the following are a few of the main historic exhibits ; Newcomen Engine, Boulton and Watt Engine, Trevithick's Engine, Murdoch's Locomotive, Trevithick's Locomotive, "Puffing Billy" Locomotive, "Rocket" Locomotive, Parsons' Original Steam Turbine, Panhard Motor Car, and many other objects of fascinating interest.

In July last Sir Richard Glazebrook contributed an excellent letter to *The Times* on the subject of obtaining the desired space, and asked me if I would do something in the same direction. In my letter I pointed out that the Science Museum is one of the most important factors we have in this country for spreading knowledge of the various inventions and designs from which this country has benefited so largely in the past. The Museum in the future ought to be of still greater service if the Government would give the necessary aid for the immediate completion of the new block.

Large numbers of the younger members of the nation from time to time visit the Museum, this being of the greatest possible value in showing the youthful mind not only how much the Empire has already benefited from the historical display there set forth, but still more how much the Empire must depend upon the rising talent amongst us to carry on the good work, and thus enable the important position which it occupies in the world to be maintained.

In 1919 I brought up to London for the day about three hundred boys from my Company's Works in Sheffield, including those from a combination of several of our departments known as "The Nursery." One of the sights the boys enjoyed most was, they said, their visit to the Science Museum, with its unique features. They were intensely interested, and in the essays afterwards presented on this visit, the Science Museum played by far the most prominent part.

As an instance of modern progress which would make our forefathers stare I may say that this party left Sheffield—some 160 miles away—at 7.30 a.m., arrived at Marylebone Station at 11 a.m., and visited the British Scientific Products Exhibition; these visitors were very kindly received by H.R.H. the Duke of York at the Science Museum, South Kensington, spending two hours there ; they spent one hour in Westminster Abbey "all to themselves," left Marylebone at 6.15 p.m. and their train was, by a fortunate coincidence, followed by one of our largest airships for some fifty miles. They returned safe and sound to Sheffield by 9.45 p.m. I was much indebted to Sir Sam Fay, who made all the special arrangements for the party.

SECTION VIII

Education

TECHNICAL EDUCATION.—In considering the question of modern technical education it is particularly interesting to note how the attitude has changed during the last fifty years, and for the better. In Dr. Percy's Presidential Address to the Iron and Steel Institute, previously mentioned, considerable space was given to the consideration of this subject. Whilst he was naturally desirous to increase knowledge, some of us will not altogether agree with his attitude towards the technical education of artisans. In one section of his Address, Dr. Percy said:

" It is, I think, to be regretted that not a few of the professed friends of technical education should have indiscreetly attempted to imbue all our artisans with the notion that the one thing which at present they urgently need is technical education, and that it will be certain to benefit them all alike. Now they will naturally be inclined to interpret the word benefit as meaning pecuniary advantage, or, in other words, an increase in wages. Believing as I do that this notion is incorrect and may be mischievous inasmuch as it is calculated to inspire a large class of our artisans with hopes which will never be realised, I venture to submit it to my hearers for their consideration. What is here meant by technical education is special instruction adapted to special artificers in addition to what they can acquire in the ordinary practice of their respective arts. Of the advantages of such instruction to many of our artificers, there cannot, I presume, be two opinions. But, on the other hand—and this is the point to which I desire to direct the particular attention of my hearers—I contend that there is a large number of artisans who will not be rendered more competent by instruction of that kind. In support of this contention let me adduce file-cutters by way of example, and others, whose sole industrial work is the performance of one and the same mechanical operation. Nothing in the way of manipulation is more calculated to excite surprise and admiration than the marvellous skill which a file-cutter displays in the practice of his art. This is, indeed, an illustration of technical education in the truest sense.

" It would, I think, puzzle some of those gentlemen who talk so glibly and profusely about technical education to suggest an improvement in that of the file-cutter. Let him be saturated with knowledge of all the mysteries of iron and steel, and he certainly would not in consequence become a more skilful artificer, any more than would a sculptor by being informed that the marble on which he operates is composed of carbonic acid and lime. Nevertheless, if our file-cutters and others desire special scientific instruction in iron and steel craft, no one can reasonably object to their having it."

Dr. Percy then referred to the important work of the late Sir Bernhard Samuelson, to whom he considered was due the credit of having been the first to succeed in convincing the House of Commons of the national importance of technical education in its widest sense, and to induce it, in 1868, to grant a select committee to inquire into the provisions for giving instruction in Theoretical and Applied Science to the industrial classes. He said : " If all the advocates of technical education had been as enlightened on the subject as Sir Bernhard, had acted as judiciously and disinterestedly, I should have been silent upon it. In order to guard against the possible misinterpretation of what I have said on that subject, I may be permitted to state that all the best years of my life have been spent in trying to aid the diffusion of special scientific knowledge in that branch of the industrial arts with which early in life I became fascinated, to which I have ever since devoted myself, and in which I feel as keen an interest as ever." With this latter portion we can all agree, but as regards the earlier portion not entirely. Surely any artisan must be improved by acquiring increased knowledge.

Let us for a moment contrast the views of the present Labour Party. In a pamphlet entitled " The Education and Training of Teachers," recently published by the Trades Union Congress and the Labour Party, it is stated that at the very outset of the democratic movement there were various people who insisted that a much more comprehensive system of education must accompany the change in the method of government ; that an uneducated democracy would be something like an anarchy. They did not use the word " education " in its narrower sense, but the theory that lay behind was that to govern anything, even himself, a man must have had a certain training ; that it was a suicidal policy to put the government of the country into the hands of men who were uneducated—untrained, unacquainted with the knowledge and aspirations of the human race. They were not listened to, and the democratic experiment went on—not exactly a complete success. Presently the labouring classes themselves began to realise that to use the power put into their hands they needed this training. A certain and increasing measure of education has been given, and although there are few people who would be ready to assert that it is enough, it is imperative that what has been given should be as efficient as possible.

With these two sets of views before us, it is possible and interesting to be able to make a comparison between 1870 and 1923, naturally much to the benefit of the later period, showing the great advance made by the workers in the desire to obtain more and better educational facilities.

Sheffield Trades Technical Societies.—Whilst in a general way Dr. Percy may have been correct in his remarks, there was hardly recognised sufficiently the great importance of trying to teach the workmen true and correct principles of the trades in which they were engaged. Surely this would make them far more valuable, not only to themselves but to the community at large. In this respect therefore I would call attention to the valuable work being done by my friend, Professor W. Ripper, C.H., D.Eng., D.Sc., J.P., the Dean of the Faculty of Engineering in the Sheffield University and the Founder of the Sheffield Trades Technical Societies. These Societies cover the following six Sheffield industries : Cutlery, File, Silver, Edge-Tool and Saw, Foundry, and Rolling, Tilting and Forging. It will be noted that in the designations

given is included one of the very trades referred to by Dr. Percy, that is File Cutting.

Professor Ripper's object was that this movement might form, as it has done, a most useful connecting link between the University on the one hand and the various industries on the other.

The Societies are formed on democratic lines, electing annually their own officers and council, and receiving from the Department of Applied Science assistance in the organisation of the movement. Each trade is thus responsible for the lectures, discussions, and research work that is undertaken for that trade, and, as all sections of the trade are represented on the Councils, there is in each case a governing body of practical and experienced leaders who are directing the attention of the trade to the various problems and issues which the lectures are planned to solve.

The meetings are held at the University, so that at least each month the various Societies are brought into direct contact with the various activities of the University including, of course, the Applied Science Department, and can avail themselves of the latest scientific and technical knowledge, should they desire to do so, on any particular problem.

This movement has proved most excellent with regard to providing courses of lectures and promoting the reading and discussion of papers on subjects connected with the respective trades, with special reference to the needs of that large body of workers in each trade who are neither students of technical institutions nor members of scientific societies.

The lectures are given in a language which can be readily understood by the workmen, who are gradually becoming accustomed to the more scientific point of view with regard to the problems which have to be met in modern industry.

An incidental advantage is that the knowledge gained enables the workmen to follow, at least to some extent, the lectures of the more advanced Scientific Societies with profit and understanding.

No less than 137 Lectures and Discussions have been given on subjects selected by the various societies. Three courses of lectures on industrial administration and four courses of lectures on Metallurgy have been arranged with the Department of Applied Science to suit the special needs of the lighter Sheffield industries. Six visits to modern works have afforded opportunities to study up-to-date manufacturing methods ; and seven exhibitions of foreign samples of goods made by competitors of the Sheffield trades have been followed by valuable discussions. Also an important research on stains in electro-plated work has been successfully accomplished.

The most important result, however, is the bringing of all sections of the trades together to consider the best means of solving the many problems which confront them. For the Session 1922-23 (September to March respectively) no less than thirty-seven different papers were read and discussed.

I claim, therefore, that the artisan so trained must be a better and more valuable man, not only benefiting himself but also the State.

It will be seen that the Applied Science Department of the University, with all its facilities for mechanical testing, chemical analysis, metallographic installation, and other branches, is freely at the service of those engaged in these studies even if outside the University. It seems certain that this movement will spread still further with the best possible

results to the trades and to those engaged in them, and the University feels that in encouraging this movement and in opening out these new opportunities to the large class of workers, who have hitherto been outside such influence, a useful piece of work is being done that may be far reaching in its effects both economically and socially.

Birmingham Industrial Laboratories.—I understand that those concerned in organising and working the Industrial Research Laboratories of the Birmingham Corporation at the Gas Department, Council House, are also trying to bring about similar results, though I believe the work done has not yet extended so far as that in Sheffield. The Birmingham Laboratories are in charge of Mr. C. M. Walter, and have been equipped with a view to collaboration with manufacturers wishing to have work of scientific and technical nature carried out for them, and if required this is treated as confidential. The plant includes an experimental foundry and heat treatment shops, so that Metal Melting and Alloying, Annealing, Heat Treatment, Autogenous Welding and Metal Cutting, Physical and Mechanical Testing of Ferrous and Non-Ferrous Metals, Electrical Testing, and the testing of Temperature Measuring and Recording Apparatus, are carried on there.

University Methods of Training in Metallurgy.—At the important and most useful Inter-University Metallurgical Conference arranged by your University and held here in February last, there were present some fifty delegates and representatives from London, Birmingham, Sheffield, Leeds, Cardiff, Manchester and Glasgow.

I have carefully read over the interesting discussion which then took place ; this certainly deserves to be circulated more widely than it has been in our technical papers. In fact, it seems to me that an account of the Conference might well be presented as a Report to the Iron and Steel Institute for further discussion there.

A wide variety of opinion was expressed. Some of those who took part in the discussion considered that, in addition to Metallurgy itself, Mathematics was the best subject with which to train students' minds ; others held that Chemistry and Physics were the most important subjects, and some that Economics, Book-keeping and Psychology should not be overlooked. It is not easy to determine the exact curriculum which suits the mind of each particular individual. No doubt a general combination of the subjects, in so far as time will permit, is best. In any case, mental training on any one of the several subjects must be of great service.

Professor Turner in an excellent opening Address claimed that, provided Metallurgists were given a sound Pure Science grounding, it did not matter so much what was the form of the final stages of their Metallurgical education so long as it was the means of efficiently completing their mental training. Naturally this was accomplished by means of lectures and practical work in Metallurgy and other subjects. "Character" was quite as important as an efficiently trained mind. He was a strong supporter of the maxim "Metallurgy for the Metallurgists" and advocated it, but on the standard of professional training by means of Universities.

It is interesting to note that Professor Turner pointed out that, for want of proper teaching, certain misinterpretation or misunderstanding of results by chemists was largely responsible for the postponement by some twenty years of the knowledge of certain properties of cast

iron. He thought that at the end of the present great trade depression Metallurgy was one of the most promising of the professions, and that it is only rational to think that men who had received Metallurgical and Commercial training were better qualified to occupy important posts in the field of Metallurgy than those with no knowledge of the technical side of their industry.

Professor Thompson of the Manchester University, considered the only ideal Metallurgical course in the world was that taken at Paris, where the student spends three years obtaining a Pure Science Degree, and then after a further five years' work took his Metallurgical Degree. He considered that a really first-class Metallurgist ought to know something about everything, and everything about something. Universities endeavoured to give instruction in "Something about everything," whilst the more specialised information was assimilated in the works.

Professor Thompson stated that if he had to remit any subject from his Course it would certainly be Metallurgy rather than the Pure Science subjects of Mathematics, Chemistry and Physics. Foremen were expected to have a detailed knowledge of the special branch of the industry in which they were engaged, while the staff of a works had to be trained so that it could undertake its technical control.

Amongst the interesting contributions to the discussion I notice certain remarks by Mr. H. Heape, of Birmingham, which are worthy of repeating. He thought that a well trained eye was as important to Metallurgists as a well trained mind, and he would therefore like to see steps taken to improve the students' powers of observation. I quite agree with this important conclusion. It is astonishing how unobservant are some individuals simply for want of training that particular faculty.

During the Conference some of the Delegates gave details and time tables in their respective Departments.

Before closing the Conference the Chairman, Mr. May, asked the Delegates to arrive at some definite conclusions on the subjects discussed. These are set forth as follows :—

1. That the pure Sciences of Mathematics, Physics, Chemistry and Physical Chemistry are of the greatest importance and should be given a large part in a Metallurgical course. This was carried unanimously.

2. That specialisation is undesirable during training and should be left until after graduation. This was carried with one dissentient.

3. That the vacations at Christmas and Easter should be shortened, if necessary, to allow at least two months being put in at works during the summer. This was carried unanimously.

4. That an adequate training in a second modern language should be included in a Metallurgical course. This was carried with three dissentients.

5. That the Conference emphasised the importance of a University Metallurgical Society to the student in his work. This was carried unanimously.

6. That it is desirable to include, if possible, a course of industrial economics in a course of Metallurgy. This was carried with one dissentient.

7. That no course is complete, unless in his final year the student takes an interest in modern research. This was carried unanimously.

8. That the true function of a University is to produce sound citizens. This was carried unanimously.

This excellent discussion and its conclusions ought to prove of great service in helping to clear up the controversy which has for so long continued with regard to this important subject. In offering these few remarks and suggestions I have only touched upon the fringe of this question, but if any words of my Lecture lead to still more careful thought being bestowed upon it, I shall be fully repaid.

Section IX

Research

Ramsay Memorial Fellowships.—As one of the Trustees of the Ramsay Memorial Fellowship Trust, I call attention to the useful work being done by this Body, in the hope that some of these Fellowships will be taken up by Birmingham men. In a recent speech Sir Gregory Foster, Provost of the University College, mentioned that the sum of £50,000 had been raised in this country in memory of this great Englishman, Sir William Ramsay. To this should be added the capital value of Fellowships contributed by the Dominions and foreign countries, so that the grand total of the Memorial Fund now amounts to the considerable sum of £120,000.

The work of the Trust has consisted of two principal features, one being the establishment of a number of Fellowships for British chemists tenable in any University or College of the United Kingdom. The second is the establishment of Fellowships by the Dominions and foreign Governments.

Younger chemists selected from the Dominions and abroad have been brought in to undertake research work in this country. The results have already proved satisfactory. Some of the countries participating have been Canada, Denmark, France, Greece, Italy, Japan, Holland, Norway, Spain, Sweden and Switzerland. Since 1919 there have been 21 Fellowships.

Yarrow Gift for Endowment of Research.—As another instance of endowed research, in this case representing the liberality of one of our own countrymen, mention should most certainly be made of Sir Alfred Yarrow's magnificent gift of £100,000, which was announced in February last. The Council of the Royal Society has decided to use the larger part of the income in the direct endowment of research by those who have already proved that they possess ability of the highest type for independent research. To this end a number of Professorships will be originated, of a type similar to the Foulerton Professorships, which were founded by the Society in 1922 for research in medicine.

The Professors will be expected to devote their whole time to scientific research, except that they may give a limited course of instruction in the subjects of their research to advanced students. By thus earmarking research as a definite profession, the Royal Society have wisely established a policy which must be of the greatest possible service to this country.

Alloys of Iron Research.—It may be interesting to state that a new Iron Alloys Research Committee has recently been formed as an offshoot of the old Alloys Research Committee, which originated

in 1889 at the instance of the Institution of Mechanical Engineers. I was asked to join this Committee in 1891, and as representing the Institution of Civil Engineers and the Institution of Naval Architects, along with Sir John Dewrance, Sir Thomas Kirk-Rose, Dr. Carpenter, and Mr. Harbord, I am also a member of this new Committee. The work of the old Committee continued down to December of last year. Amongst its members have been those noted for their knowledge and research on both Ferrous and Non-Ferrous Alloys. The information gained has been of great service to the country, including the famous reports of the late Sir William Roberts-Austen, Dr. W. Rosenhain, F.R.S., and others.

Upon the reconstitution of the Committee in December last it was decided to devote attention for the present to Alloys of Iron only. Sir John Dewrance, the Chairman of the former Committee, was re-appointed to that post, and the members mentioned above were co-opted.

Sir John Dewrance has already raised about £12,000 including the amount to be furnished by the Council for Scientific and Industrial Research. He hopes to obtain by private and by Government aid, something like £30,000, spread over six years. These important Researches will be carried out at the National Physical Laboratory and other Metallurgical centres as occasion demands. I trust that Sheffield and Birmingham will be called in to give their help in view of the great service these two centres have rendered in the past. This important Research is mentioned as showing that this country intends to keep ahead and maintain, as in the past, its position of being the pioneer of Metallurgical knowledge, including Alloy Steels.

American Views on Research.—In some recent wise words my friend, Dr. G. E. Hale, Director of Mount Wilson Observatory, and Chairman of the National Research Council of America, in his interesting paper on "A National Focus of Science and Research," says that it is not only in the material world that Science is useful to mankind. Its greatest aim and object is the discovery of truth, which it pursues without fear of embarrassing consequences. Science sets before us a high example of honest judgment and an open mind, reversing its conclusions without hesitation when new evidence demands. And as it builds up through the centuries, by long and painful search, a great body of knowledge for universal benefit, it spreads before the imagination a picture which no artist could hope to rival. No material service of science to daily life, such as the accurate marking of time or the navigation of the seas, can compare in value with its overthrow of earth-centred mediævalism and its revelation of the universe. The enlarged conception of human possibilities thus afforded, the escape thus effected from the dominance of enforced and arbitrary thought, are reflected in the advance of the modern world. And the sweeping picture that science spreads before us is unmatched in its appeal to the imagination and its stimulus to progress.

American Research Laboratories.—From the interesting and most valuable Bulletin of the National Research Council, published in Washington, D.C., there is obtained some idea of the great amount of Research Work being carried out and the large number of Research Laboratories in industrial establishments in the United States. It is astonishing to find that there are something like 500 different Laboratories,

which helps to bring home to us in this country the excellent way in which the United States is going ahead in this respect.

As an instance may be mentioned the Research Laboratory of the General Electric Company, the head of which is Dr. W. R. Whitney, who has 2 Assistant Directors, 50 Chemists, 12 Physicists, 13 Engineers, 50 Research Assistants, also Machinists, Glass Blowers, Electricians, and Clerks. Amongst the subjects dealt with are: Special attention to devising new forms of electric lights and improving existing forms; the development of the Coolidge X-ray tube; the invention of new and the development of existing forms of electrical equipment and apparatus; the study of metals and alloys for electrical uses; wireless transmission development; the study of insulation; and many fundamental scientific researches in physics and chemistry.

Another instance is the Du Pont Company, whose Chemical Department operates five Research Laboratories in addition to organisation at its main office. On the Research Staff there are 200 graduated Chemists and Engineers, 122 other salaried employees and 200 pay-roll employees. On actual Research work, practically working full time, there are 522 individuals superintending the manufacturing operations of the Du Pont Company, including miscellaneous chemicals, dyes and intermediates, explosives, artificial leather, rubber goods, plastics, pyroxylin solutions, lacquers, paints and varnish, including the production of miscellaneous raw materials such as mineral acids and nitrate of soda. In addition to the foregoing there are five other Laboratories.

One of the greatest living Scientists, Sir J. J. Thomson, Past President of the Royal Society, not long ago paid a visit to America and went through the Research Departments of some of the large manufacturing firms just mentioned. Whilst these Laboratories have often been established in the face of considerable opposition, it is now generally admitted that the Research Department, even from the monetary point of view alone, is one of the most profitable possessions of manufacturing concerns. Moreover, however great the necessity for economy may at times prove to be, the cost of the Research side of the work should be the last to be reduced.

Sir Joseph has pointed out that the scale of the Laboratories in the United States is far greater than anything in Great Britain, and much of the work carried out is fundamental scientific work, worthy of a University Laboratory. On the other hand, he says the American Universities do not seem designed to produce a large number of men qualified to take up advanced Research work, and mentioned that few of the Science students have the necessary equipment in mathematics, and the stern training which a good honours man in a great English University has to go through appears to be unknown. The system may be good for the average man, but a successful Research Institute requires something more than the average man; it needs men with high scientific knowledge. In this respect, Sir Joseph states Great Britain has a distinct advantage in the competition which is before us. Coming from such a high authority this indeed is satisfactory.

To show the attention being paid in America generally to the subject of Research it is interesting to note that a new building is now being erected in Washington, close to the famous Lincoln Memorial, for the National Academy of Science and the National Research Council. The total cost is to be about £300,000.

Section X

Development of Engineering

Early this year Professor F. W. Burstall, M.A., Dean of your Faculty of Science, gave an excellent address to the Women's Engineering Conference, upon the History of Mechanical Engineering. He considered that the first development of Engineering came at the end of the Great Rebellion somewhere about 1660, and that the mental outlook then began to change largely from the immaterial and philosophical into the application of Science for the purposes of man. The brilliant intelligence gathered round Charles II developed in the direction of the improvement of what may be termed mechanical forces.

In 1705 came the production of mechanical power in the Newcomen Engine, brought into use in this country largely because of cheap coal being accessible, and also because of the means it provided of improving the condition of the mines; owing to increased depth these required draining by pumping, which was not possible except by the utilisation of mechanical energy. Old prints exist showing that in 1720 tilt hammers and rolling mills were driven by wooden shafts actuated by water power.

With the exception of these applications, and the use of water wheels for grinding, there were few attempts to utilise mechanical power prior to 1770, and Professor Burstall is doubtless correct when he says that the great distinction between the old world and the new commenced about this date. This is a striking point to have elucidated, and it has not previously been put so clearly and so well.

Professor Burstall adds that whilst the genius of Watt first laid down the foundation for these wonderful advances, the great work of Boulton, Murdoch, and Wilkinson, must also be remembered. Murdoch first brought out the slide valve for the James Watt engine, and Wilkinson devised the machine tools at the Soho Foundry where the first pumping engines were constructed as early as 1760. It should also be added that it was due to James Watt, Junior, that mechanical power for the propulsion of steamships was introduced in 1807.

In words well worthy of being borne in mind by all of us, Professor Burstall then went on to ask "What of the future?" What is going to be the result of all this present enormous development by civil, mechanical, electrical, metallurgical and chemical engineers? He pointed out that if we are careful in learning how to handle the immense powers of nature put at our disposal, with thought for others, then the world will be greatly benefited; but if we are selfish, then like Rome we shall destroy ourselves. In this respect, therefore, the factor of comfort and progress must be that of the mean value, that is for the average man. If you get ahead of the average man he will not have your rulings. Therefore try to pull him up to your level, not push him down. With this I am heartily in agreement. Although Professor Burstall's remarks were intended for our women, they are equally interesting for our men.

In Conclusion, let me say to the younger men of the Society I am addressing, some of whom at times during their career may be cast down by apparent want of success, do not be disheartened or discouraged ; renew your efforts ; try again. This is specially applicable to those engaged on research work which includes and leads to discoveries and inventions. It must not be forgotten that the great achievements of the human mind and effort in new directions are at first generally received with distrust. I can speak from the experience I have had in developing my own inventions. Perseverance in the highest degree is required to achieve success.

Remember, too, that except in the few cases which can almost be counted on the fingers of one's hand, success can only be attained by years of hard work and painful toil. Nevertheless, I firmly believe, as Shakespeare has well said :

> " Men at some time are masters of their fates ;
> The fault, dear Brutus, is not in our stars,
> But in ourselves, that we are underlings."

I also ask you to read and ponder the beautiful and noble words of Milton on education presented in the foreword of this Address. Take them to heart, remembering that they were written by one of our greatest Englishmen, who himself must have struggled against the many difficulties, some of them apparently insuperable, with which owing to his blindness he was surrounded. He toiled hard and long against many obstacles in his path ; nevertheless, how wonderfully he overcame them and achieved that great position which is so deservedly his in the Anglo-Saxon Roll of Honour.

I will quote the wise words of one of our great men of the day, the Earl Balfour, himself a philosopher of no mean order, who said not long ago, " In the progress of Engineering Invention and Discovery lies almost the only hope of bettering the material conditions of mankind." As without doubt under the term " Engineering " he included the wider and fuller meaning, covering all branches of scientific work, amongst them Metallurgy, Chemistry or Electricity, his words show how bright and attractive is the future for the mind trained and well versed in scientific knowledge.

Similarly another great Englishman, Carlyle, has pithily said, " The true epic of our time is not ' Arms and the Man ' but ' Tools and the Man '—an infinitely wider kind of epic."

In this Address I have made a number of quotations, duly mentioning the source, because it seems to me that my readers will be far more interested in these wise sayings than in such remarks as I might have made regarding subjects outside my own line of work. Disraeli has well said, " The art of quotation requires more delicacy in the practice than those conceive who can see nothing more in a quotation than the extract." It is because these quotations, taken from a wide range of literature, so aptly and clearly express much of what was in my own mind when preparing this Address, that I have made full use of them, feeling sure they would also interest my readers.

It has been a great pleasure to prepare and present this Address to your Society, and if the final result is that help of any kind has been afforded the younger men in our midst, I shall feel amply rewarded.

Appendix

Appendix

TYPES AND METHODS OF RESEARCH

Through which Discovery and Invention may be attained, as described by the late DR. G. GORE, F.R.S., in his book

THE ART OF SCIENTIFIC DISCOVERY

In view of the great importance and valuable nature of Gore's advice, since it applies just as much to-day as when first given, the following extracts are quoted " On the General conditions and methods of research in Physics and Chemistry " as set forth in his admirable book *The Art of Scientific Discovery.*

Gore says that many scientific men hesitate to undertake original research from a fear of the great difficulty of the task and of repeating experiments which others have already made, and also because they do not know how to select suitable subjects ; and, as one of the most effectual preliminary conditions of ensuring success in research is a thorough study of the general and special methods and conditions of discovery, it is hoped that such persons will be induced to attempt original investigation by the aid of the suggestions contained in this book.

Although men have during all modern time made discoveries in Physics and Chemistry, and many eminent investigators have occupied and are still occupying a large portion of their lives in original scientific research, the conditions of success and failure in the pursuit of original scientific inquiry and the methods employed in making discoveries remain for the most part unknown to ordinary persons.

In nearly all cases investigators, from some cause or other, have not troubled themselves to describe the actual circumstances which gave rise to their discoveries, and have thus failed to leave behind them the ladder by which they ascended, and by which others might, to some extent at least, have been assisted in the pursuit of similar objects. Faraday, and particularly Kepler, did, however, leave an account of a few of the failures as well as the successes of their researches.

Whilst I do not forget Dr. Whewell's assertion that, speaking with strictness, an " Art of Discovery " is not possible ; that we can give no rules for the pursuit of truth which shall be universally and peremptorily applicable ; and that the helps which we can offer to the inquirer in such cases are limited and precarious, I share his hope that aids may be pointed out which are neither worthless nor uninstructive.

To some the very proposal to write a book on such a subject may appear presumptuous ; and even among scientific investigators there are those who consider that the methods of discovery are incommunicable. But original scientific research is not a supernatural operation. If it

were, it would not be possible to make discoveries by means of our natural faculties, nor to communicate them by ordinary means. It is a natural process, and being such, it must have laws according to which it operates. It is effected by means of our mental powers, and is therefore subject to the rules of mental action, and is communicable by ordinary natural methods. It is also being reduced, as knowledge advances, to rules of action, and will in time become one of the noblest of all intellectual employments. It is well known that by obeying the laws of Nature we learn how to employ them ; and by studying the principles of Science, and the action of the human mind in original research, we may reasonably expect to learn the essential conditions upon which success in scientific discovery depends.

In Gore's book, Chapter II deals with Special Methods of Discovery, Personal Preparation for Research ; Chapter XII with Actual Working in Original Scientific Research, General Conditions of Scientific Research ; and Chapter XIV, General view and basis of Scientific Research.

The following Table represented the types of Research and methods by which discovery and invention may be attained :

1. Aid to Analogy.
2. Hypotheses.
3. Analysis and Synthesis.
4. Application of—
   (*a*) Electricity to bodies.
   (*b*) Heat to substances.
5. Asking questions and testing such questions.
6. Assumptions that—
   (*a*) There is certainty of all the great principles of science.
   (*b*) Complete homologous series exist.
   (*c*) Converse principles of action exist.
   (*d*) Certain general statements which are true of one force or substance are true to some extent of others.
7. Combined action of many observers.
8. Comparisons of—
   (*a*) Facts, and collecting similar ones.
   (*b*) Collections of facts with each other.
   (*c*) The orders of collections of facts.
   (*d*) Facts with hypotheses.
9. Deducting process.
10. Employment of new or improved means of observation.
11. Examination of—
   (*a*) Common but neglected substances.
   (*b*) Effects of forces on substances.
   (*c*) Effects of contact on substances.
   (*d*) Effects of extreme degrees of force.
   (*e*) Extreme or conspicuous instances.
   (*f*) Influence of time upon phenomena.
   (*g*) Neglected truths and hypotheses.
   (*h*) Peculiar minerals.
   (*i*) Unexpected truths.

- (*j*) Rare substances.
- (*k*) Residue phenomena.
- (*l*) Residues of manufacture.
- (*m*) The ashes of rare plants and animals.

12. Extension of—
   - (*a*) The researches of others.
   - (*b*) The researches of neglected parts of science.

13. Inductive process.

14. Investigations of—
   - (*a*) Exceptional cases.
   - (*b*) Unexpected phenomena.
   - (*c*) Classification unexplained.

15. Means of—
   - (*a*) Converse experiments.
   - (*b*) Hypotheses.
   - (*c*) "Homologous Series."
   - (*d*) Instruments of great power.
   - (*e*) Improved methods of intellectual operation.
   - (*f*) Measurements.
   - (*g*) The method of curves.
   - (*h*) The method of least squares.
   - (*i*) The method of means.
   - (*j*) The method of residues.
   - (*k*) New instruments.
   - (*l*) Modes of observation.
   - (*m*) Observations.
   - (*n*) More intelligent and acute observation.
   - (*o*) Additional observations by known methods.
   - (*p*) Periodic functions.
   - (*q*) More refined methods of working.
   - (*r*) Repetition of experiments.

16. Simple comparisons of facts of phenomena.

17. Search for—
   - (*a*) So-called "impossible" things.
   - (*b*) One thing and finding another.

18. Subjecting series of forces or substances to new conditions.

19. Use of—
   - (*a*) Known instruments or forces in a new way.
   - (*b*) Improved instruments.
   - (*c*) More powerful instruments.
   - (*d*) Causes by the methods of averages.
   - (*e*) Coincidences.

20. Conditions of—
   - (*a*) Scientific Discovery.
   - (*b*) Determination of the nature of a discovery contrasted with barren reasoning.

21. Dependence of discovery upon art of exceptional instances.

22. Fundamental laws of discovery.

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